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Initial Assessment of the Introduction of Spottail Shiner (Notropis hudsonius) and Delta Smelt (Hypomesus transpacificus) into Willard Bay Reservoir, Utah.

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INITIAL ASSESSMENT OF THE INTRODUCTION OF SPOTTAIL SHINER (*NOTROPIS HUDSONIUS*) AND DELTA SMELT (*HYPOMESUS TRANSPACIFICUS*) INTO WILLARD BAY RESERVOIR, UTAH.

by

Thomas Edward Sommerfeldt

A thesis submitted in partial fulfillment
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of

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Thomas E. Sommerfeldt

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by

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Utah State University, 1984

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Spottail shiner (*Notropis hudsonius*) and delta smelt (*Hypomesus transpacificus*) were introduced into Willard Reservoir to improve the forage base for walleye (*Stizostedion vitreum vitreum*) and black crappie (*Pomoxis nigromaculatus*). Spottail shiners were stocked in early spring in 1981, 1982, and 1983. Hauling mortality was generally great and an estimated 34,500 live fish were stocked in the 3-year period. Spottail shiner reproduction occurred each year of stocking. Delta smelt were introduced in 1982 with the stocking of 15,000 adult

spawning fish. Stocking survival was estimated at 99%. Freshly spawned eggs were also obtained and placed in a tributary to Willard Reservoir. Shoreline seining produced 29 young-of-the-year delta smelt during June 1982.

Growth of the captured young-of-the-year spottail shiner and delta smelt in Willard Reservoir compared favorably with growth found in their respective native waters. Stomach analysis indicated food habits were similar to those in native waters. Food habit analysis of young-of-the-year walleye, black crappie, spottail shiner, and delta smelt indicated very little overlap of food organisms between the four fish species.

Spottail shiners occurred in 3 of 56 walleye stomachs containing food items in 1982 and 3 of 41 stomachs containing food items in 1983. Delta smelt were not found in the 132 walleye stomachs examined. However, six adult delta smelt were found in the stomachs of angler-caught walleye in April 1983. No spottail shiners or delta smelt were found in 79 black crappie stomachs examined in 1982 or 62 stomachs examined in 1983. Low utilization of spottail shiner and delta smelt was attributed to the low relative abundance of the two species in Willard Reservoir.

(116 pages)

INTRODUCTION

Fishery management in the western United States has been primarily oriented toward salmonid fishes in the past (Wydoski and Bennett 1981). Recent development of reservoirs for irrigation, municipal, and industrial purposes has created new systems that favor coolwater and warmwater fishes and thereby adds new responsibilities for fishery management in the west. Utah, for instance, has no native warmwater sportfish (Johnson 1983). Native coldwater sportfish originally consisted of two subspecies of cutthroat trout (*Salmo clarki*) and four species of whitefish (*Prosopium* sp.), all generally unsuited for warmwater reservoir habitat. Hence, non-native warmwater predators have been introduced to provide a sport fishery in these reservoirs. The native preyfish have, without exception, failed to provide suitable forage bases for these introduced predators (Johnson 1983). Stocking of non-native forage fish has been one method used in an attempt to establish a suitable forage base.

One such warmwater reservoir habitat is Willard Bay Reservoir, Utah. Self-sustaining populations of walleye (*Stizostedion vitreum vitreum*), black crappie (*Pomoxis nigromaculatus*), and channel catfish (*Ictaluras punctatus*) have since become established. Poor growth of walleye after their second year of life has occurred due to a lack of suitable forage (Summers 1971; Pitman 1973). Two species, the spottail shiner (*Notropis hudsonius*) and the delta smelt (*Hypomesus transpacificus*), were selected for introduction into Willard Reservoir to improve the forage base. The purpose of my study was to evaluate the initial success of the introduction of these forage species. The study was part of an ongoing project to assess the overall impact of forage fish introduced into Willard Reservoir.

OBJECTIVES

Objectives of the study were:

1. To determine qualitatively the success of the introduction of forage fish species, i.e., did they successfully reproduce and achieve growth comparable to that in native areas?

2. To determine the diet of young-of-the-year (yoy) and older individuals of the two forage species.

   A) Compare diet with diet in native areas.

   B) Compare diet with that of selected yoy resident species.

3. To determine use of the introduced forage species by walleye and black crappie.

DESCRIPTION OF STUDY AREA

Willard Bay Reservoir was formed in 1964 from Willard Bay of the Great Salt Lake. The reservoir is part of the Weber Basin Federal Reclamation Project designed to provide water for industrial, municipal, and irrigation purposes and hydro-electric power for the Ogden, Utah area.

The original Willard Bay was converted into a freshwater impoundment by the construction of an earthen dam 21 km long and 10.7 m high (Figure 1). This dam encloses the reservoir except for a portion along the east side where high ground abuts the reservoir. The dam is designed to "float" on the old lake bed and is covered on the reservoir side by rock rip-rap to prevent erosion.

The major source of water for Willard Reservoir is the Ogden and Weber rivers. The rivers join just west of Ogden before the Slaterville diversion dam (Figure 1). The diversion dam can divert water to Willard Reservoir by way of the 12.9 km Willard canal. A minor amount of water is contributed to the reservoir by Willard Creek which enters the northeast corner.

Willard Reservoir has a surface area of 4047 hectares (10,000 acres) at normal elevation 1288.1 m (4226 ft) and a capacity of 2.65 x

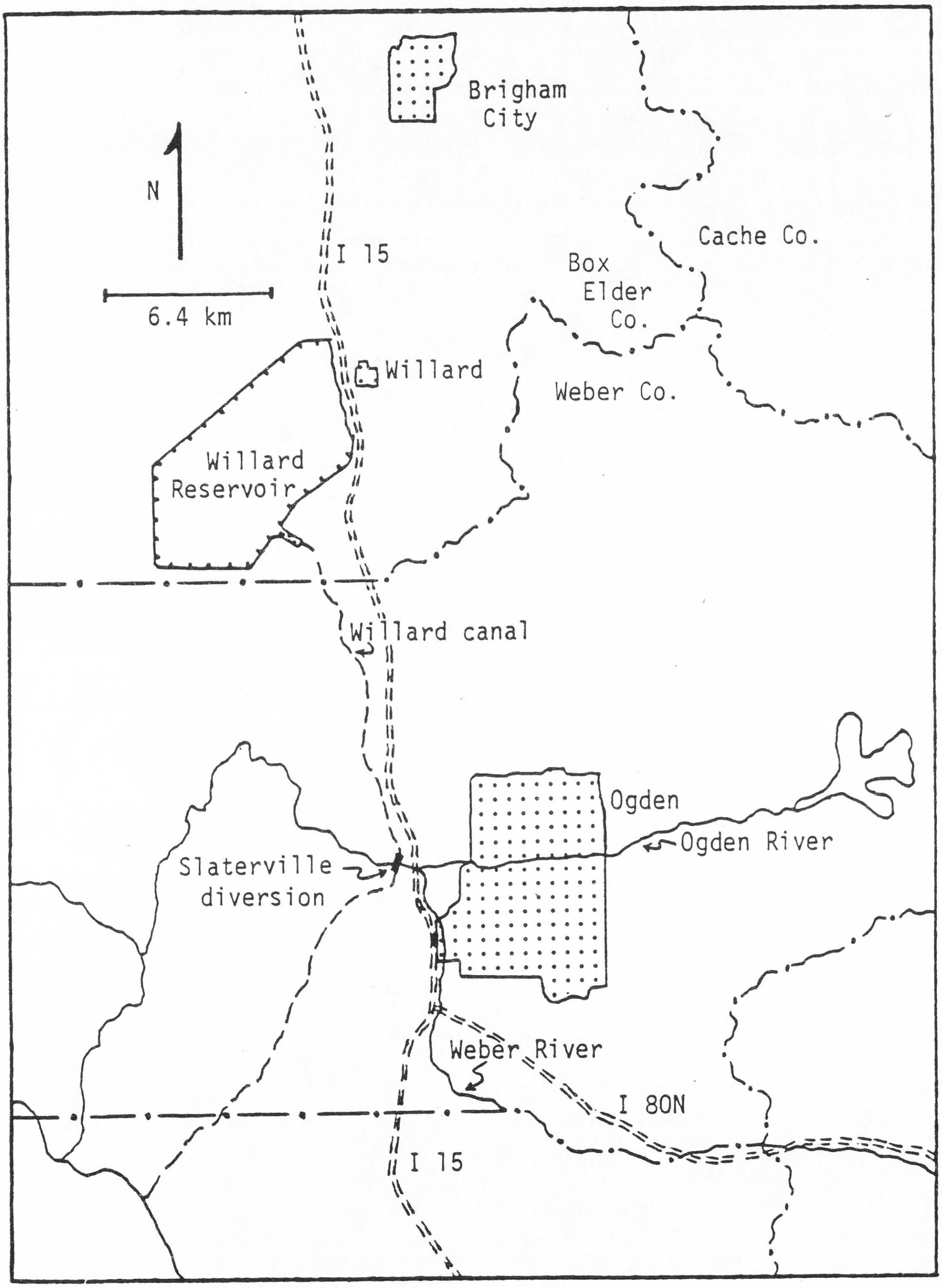


Figure 1. Map of northern Utah, showing location of Willard Reservoir.

10^8 m^3 (215,000 acre-feet) of water. At a surface area of 4047 hectares, maximum depth is 7.6 m and mean depth is 5.5 m (Summers 1980). Sand and silt are the major substrates with a few raised rock-rubble areas present. The reservoir is basically flat across the entire bottom; steeply sloping sides occur only as the dam is approached. This characteristic results in an unusually low volume-to-surface ratio. Volume may drop considerably with little change in total surface area. Water drawn off for irrigation purposes and from evaporation produces seasonal water level fluctuations. The resulting minor changes in surface area with water release are very important to the fishery. Nursery habitat along the northeast shore for walleye, black crappie, channel catfish, and spottail shiner is sufficiently protected at a reservoir elevation of 1286.9 m (4222 ft) (Johnson 1982). A drop in water level of less than 1 m dewaters much of this habitat.

Willard Reservoir is classified as eutrophic on the basis of high nitrogen and phosphorus concentrations (Table 1). Nutrient concentration data by Herron (1981) agree with this classification. Values for pH, conductivity, TDS, alkalinity, and ion concentrations for 1982 were generally lower than values cited by Herron (1981) and collected by the Weber Basin Water Conservancy District for the years 1969-1979 (Tables 2 and 3).

Table 1. Nutrient concentrations in Willard Reservoir.

Nutrient	Concentration[a] (11/23/82)	Range[b] (11/29/79)
Ortho-phosphate	16 ug/l PO_4-P	6 - 28 ug/l PO_4-P
Total phosphorus	60 ug/l PO_4-P	21 - 28 ug/l PO_4-P
Ammonia (NH_3)	116 ug/l NH_3-N	11 - 198 ug/l NH_3-N
Nitrate (NO_3)	220 ug/l NO_3-N	180 - 740 ug/l NO_3-N
Nitrite (NO_2)	15 ug/l NO_2-N	6 - 22 ug/l NO_2-N

a] Analyses performed by author according to Adams et al. 1981.

b] from Herron (1981).

Table 2. Potentiometric and solids analysis of Willard Reservoir water.

Test	Value[a] (11/23/82)	Range[b] (1969 - 1979)
pH	7.7	7.9 - 8.5
Conductivity (@ 25^{o} C)	900 umhos/cm	1062 - 1384 umhos/cm
TDS	530 mg/l	580 - 795 mg/l
Alkalinity	155 mg/l as $CaCO_3$	139 - 186 mg/l as $CaCO_3$

a] Analyses performed by author according to Adams et al. 1981.

b] from Herron (1981).

Table 3. Ion concentrations in Willard Reservoir.

Ion	Concentration[a] (11/23/82)	Range[b] (1969 - 1979)
Ca^{++}	34 mg/l Ca^{++}	38 - 60 mg/l Ca^{++}
Mg^{++}	26 mg/l Mg^{++}	20 - 30 mg/l Mg^{++}
Na^{+}	112 mg/l Na^{+}	141 - 240 mg/l Na^{+}
Cl^{-}	210 mg/l Cl^{-}	210 - 351 mg/l Cl^{-}
SO_4^{--}	16 mg/l SO_4^{--}	47 - 64 mg/l SO_4^{--}
HCO_3^{-}	189 mg/l HCO_3^{-}	176 - 230 mg/l HCO_3^{-}

a] Analyses performed by author according to Adams et al. 1981.

b] from Herron (1981).

Very little thermal stratification occurs in Willard Reservoir. Monthly temperature readings from July to October, 1979 had little difference from surface to bottom at any time (Herron 1981). A maximum surface temperature of 29 C was recorded in July 1983. Dissolved oxygen levels do vary vertically. Surface dissolved oxygen levels ranged from 5.5 to 10.8 mg/liter and bottom DO levels ranged from 0.5 to 9.1 mg/liter during July to October, 1979 (Herron, 1981).

Water temperatures cool sufficiently for ice to form on the reservoir by December. Ice conditions are variable; ice often forms and disappears throughout the winter months (Herron 1981). Ice cover generally disappears entirely by March.

Herron (1981) found that phytoplankton density in 1980 and 1981 increased dramatically in July and peaked in September. Another peak was observed in late winter. The summer peak was the result of an *Aphanizomenon* bloom and the late winter peak was a result of increases in *Asterionella* and *Fragillaria* densities. Mean density of phytoplankton at five sample sites in Willard Reservoir was over 300,000 algal units per liter of water (units being defined as single cells, colonies, trichomes, filaments, and fragments). This density indicates the high productivity in the reservoir (Herron 1981).

Net zooplankton consisted almost entirely of cladocerans, copepods, and rotifers (Herron 1981). Cladocerans were mainly *Daphnia* and *Ceriodaphnia* with occasional *Bosmina* and *Diaphanosoma*. Copepods consisted primarily of *Cyclops* and *Diaptomus* with some *Epischura*. Numerous copepod nauplii were also observed. The rotifer community was made up largely of *Chromogaster*, *Polyarthra*, *Keratella*, *Asplanchna*, and *Brachionus* (Herron 1981).

The Utah Division of Wildlife Resources initiated a stocking program for Willard Reservoir in 1965. Five species of fish, the walleye, channel catfish, largemouth bass (*Micropterus salmoides*), white bass (*Morone chrysops*), and fathead minnow (*Pimephales promelas*), were stocked in order to establish a warmwater fishery. Largemouth bass, white bass, and the fathead minnow have met with either limited success or failed to establish populations in Willard Reservoir. The black crappie, purportedly introduced by fishermen, has become established.

Currently Willard Reservoir provides a recreational fishery for walleye, black crappie, and channel catfish. These three species are self-sustaining, and no supplemental stocking occurs. Before the spottail shiner introductions, other species of fish found in the reservoir included:

Bluegill (*Lepomis macrochirus*)
Black bullhead (*Ictaluras melas*)

Brown trout (*Salmo trutta*)
Carp (*Cyprinus carpio*)
Cutthroat trout (*Salmo clarki*)
Green sunfish (*Lepomis cyanellus*)
Mottled sculpin (*Cottus bairdi*)
Mosquitofish (*Gambusia affinis*)
Rainbow trout (*Salmo gairdneri*)
Redside shiner (*Richardsonius balteatus*)
Utah sucker (*Catostomus ardens*)
Utah chub (*Gila atraria*)

The carp is the only fish of this group that has maintained a sizeable population in the reservoir. The Utah chub is no longer evident in Willard Reservoir; others are found occasionally.

Fishery studies in the reservoir have centered on the walleye because of its importance as a sportfish. Summers (1971) found that walleye in Willard Reservoir grew at a slower rate in 1970 than did walleye in Utah Lake. The average k-factor was 1.30 compared to 1.88 for fish of comparable length in Utah Lake. Walleye in Willard Reservoir were feeding upon fish, mainly young largemouth bass and carp, and chironomid larvae. The use of chironomids as food by walleye was attributed to the absence of suitable forage fish (Summers 1971).

Walleye in Willard Reservoir have shown excellent growth in their first two years of life, however, markedly slower growth rates occur as they grow older (Pitman 1973). This slow growth rate of older fish is attributed to a lack of suitable forage fish. Walleye growth rates improved slightly in 1974 over growth in previous years, apparently due to the influx of black crappie which acted as a forage base (Pitman 1974). Herron (1981) reported that 45 walleye stomachs containing prey, among 62 examined, had only yoy crappie in them. Hence, since about 1974 the crappie has served as a major part of the forage base for walleye in the absence of more suitable prey species.

BASIS FOR SPECIES SELECTED

Many forage fish introductions in the United States have been made on a trial and error basis where a species has been stocked and the results observed. For the present study, the reservoir habitat was first carefully examined. Then forage species whose habitat requirements were similar to the habitat existing in Willard Reservoir were selected for introduction.

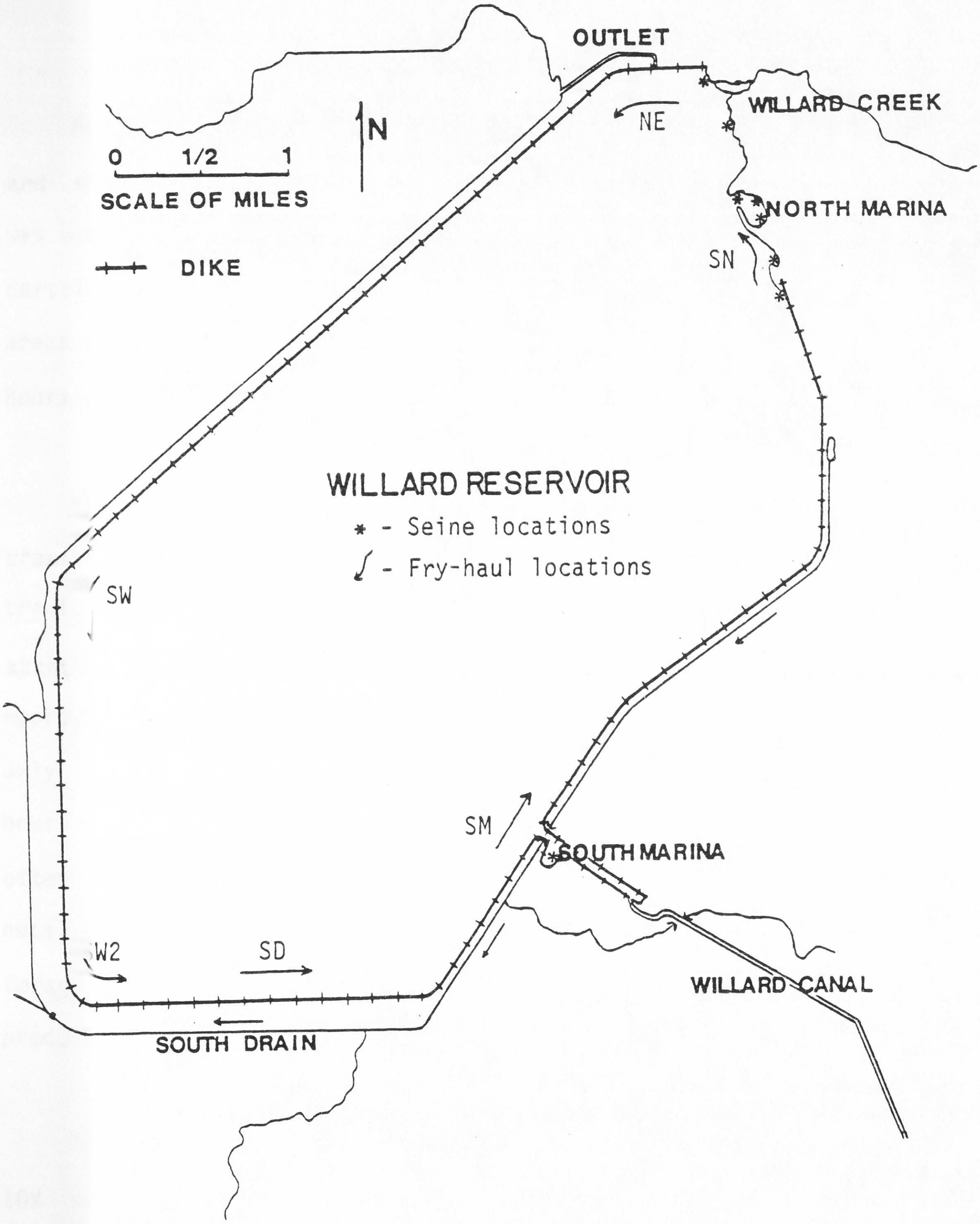
Factors influencing the selection of the spottail shiner for introduction included the abundant zooplankton and invertebrate food base, the suitable forage size, fast growth, and early maturity of the species and its tendency not to become a biological nuisance due to overpopulation. Other factors important in the selection were the available littoral areas and the vegetated and sandy substrate spawning habitat (R. Bulkley, Utah Cooperative Fishery Research Unit, personal communication).

Factors influencing the selection of the delta smelt for introduction included the abundant zooplankton food base, the large amount of open-water reservoir habitat, and available spawning areas such as rock and gravel shoals in the reservoir and inlet streams. Suitable forage size, fast growth, and early maturity of the delta smelt were again considered in the selection. This species has been known to become overabundant in some coldwater reservoirs (J. Johnson, Utah Division of Wildlife Resources, personal communication).

METHODS AND MATERIALS

Sampling of pelagic larval fish commenced 20 April 1982 using a 0.5-m tow net with a 0.79-mm mesh net and an attached cup with 0.85-mm wire mesh screen. Horizontal surface tows were 5 minutes in duration. After 20 May 1982 and beginning 28 April in 1983, a tow net with 1.0-mm mesh net and an attached cup with 0.85-mm wire mesh screen was used because large amounts of zooplankton rapidly plugged the smaller mesh net. Tows were then 10 minutes in duration.

Collections were made at six locations on the reservoir during the sampling period (Figure 2). Tows were conducted twice weekly from 1900 to 2300 until 6 July 1982; sampling was then reduced to once per week. Weather often prevented completion of all six tows. The distance covered in a 10-minute tow was estimated by measuring the associated distance covered along the shoreline for five sample tows. Mean distance covered per tow was 524 m. An estimated 103 m^3 of water were strained per 10-minute tow of the 0.5 m net. Organisms captured were placed in a collection jar and preserved in 10% formalin solution. In the laboratory, larval fish were sorted and placed in 10% buffered neutral formalin solution for storage. Rose bengal stain was used as an aid to detect fish larvae in the samples (Mitterer and Pearson 1977). Larval fish were identified with the aid of keys by Auer (1982), Becker (1983), May and Gassaway (1967), and Snyder (1981).



Figire 2. Seine and fry-haul locations, Willard Reservoir, 1982 and 1983.

Adult forage fish and post-pelagic larvae were collected by seine and otter trawl. A 1.0 x 9-m bag seine with 4-mm bobbin netting mesh was used. Due to the rock rip-rap along most of the shoreline, only certain areas of the reservoir could be seined (Figure 2). These areas were sampled weekly, from March through September, between the hours of 1900 and 2400.

When seining failed to produce sufficient quantities of fish, trawling was undertaken in deeper, unseinable water with a 4.3-m otter trawl. Otter board size was 31.5 x 61 cm. The trawl had 3.8-cm stretch mesh with a 0.4-cm bobbin netting liner sewn into the cod end. Approximately eight bottom tows were conducted weekly beginning 15 July in 1982 and 29 May in 1983. Trawling occurred during daylight hours and was 10 minutes in duration when possible. Bottom snags often prevented full 10-minute tows. Experimental gill nets, fyke nets, minnow traps, and mid-water trawling were used to collect adult forage fish. These methods were generally unsuccessful and often produced few or no fish.

Post larval and adult forage fish were immediately preserved in 10% buffered neutral formalin. Samples were sorted in the laboratory and identified with the aid of keys by Becker (1983) and Eddy and Underhill (1982). Fish were measured for total length and the stomachs were analyzed later in the laboratory. Mean total length of weekly samples was calculated. Measurements of mouth width of yoy walleye and body depth of yoy spottail shiners and ingested preyfish were taken from preserved specimens.

To determine utilization of stocked forage fish, age I and older walleye and black crappie were collected monthly from March to September in 1982 and every two months from March to September in 1983. Electro-fishing, gill nets, fyke nets, creel sampling, and seining were employed to obtain sufficient samples. Electro-fishing was the most successful.

Captured age I and older walleye and black crappie were measured for total length to the nearest millimeter and weighed to the nearest gram. Scale samples were taken for aging purposes. Scales were impressed upon acetate slides with the aid of an Ann Arbor roller press. Scale impressions were aged and distance to annuli measured on a Eberbach scale projector. Estimated lengths at annulus formation were calculated using the SHADII computer program (Nelson 1976) on the VAX computer at Utah State University. Stomachs were removed and placed in formalin solution until analyzed. Walleye stomach contents were identified to genus (fish to species when possible) and counted. Keys by Pennak (1978) and Merritt and Cummins (1978) were used to identify macroinvertebrates and zooplankton. Length measurements and volume by water displacement of food items were obtained when possible. Data were summarized by frequency of occurrence of food organisms and percent volume of food organisms for the sample of fish. Crappie stomach data were summarized by frequency of occurrence of food organisms and estimated percentage of food organisms by volume in the stomachs. Empty stomachs were not included in any calculations.

Stomachs from yoy fish were dissected under a binocular dissecting scope. Walleye, crappie, and smelt had well-defined stomachs that were easily discernible. Contents were teased out, identified with the aid of keys by Pennak (1978) and Needham and Needham (1976) and counted. Zooplankton and macroinvertebrates were identified to genus and fish to species when possible. A circular counting chamber was used to enumerate zooplankton.

Invertebrates were measured for length to the nearest 0.05 mm using a calibrated ocular micrometer incorporated into the eyepiece of the binocular scope. Cladocerans were measured from the anterior part of the head to the base of the posterior spine. Copepods were measured from the anterior part of the head to the end of the last tail segment. Other invertebrates were measured for total length.

No defined stomach was discernible in the spottail shiner, hence, contents of the first part of the digestive tube were examined. The spottail shiner also has pharyngeal arches which masticate food items and produce much unidentified matter. Percent volume of food organisms per stomach was estimated for all yoy and adult spottail shiners examined. Diets were summarized by frequency of occurrence of food organisms and mean number of organisms per stomach. Again, empty stomachs were not included in calculations.

The original design of the study incorporated statistical analysis of yoy diet data. Difficulty in obtaining adequate sample sizes of fish with similar gear and within the same time period precluded extensive statistical analysis. Diet comparisons by general trends and observations were used.

RESULTS

Evaluation of Stocking Success

Spottail shiner

Spottail shiners were obtained from Rhodes Live Bait Company, Amherst Junction, Wisconsin, in May 1981 and 1982, and June 1983. The fish were captured from Lake Superior and other locations in north-central Wisconsin. Fish were transported in 1981 and 1982 by Rhodes Company personnel and by Utah Division of Wildlife Resources personnel in 1983. Fish were stocked in the northeast section of Willard Reservoir all 3 years.

On 18 May 1981, an estimated 32,000 spottail shiners were delivered to Willard Reservoir (R. Bulkley, Utah Cooperative Fishery Research Unit, personal communication). Mortality from hauling stress 48 hours after stocking was estimated at 49% based on live-cage samples. Hence, approximately 16,000 fish survived in the reservoir which, based upon a sex ratio taken from 201 fish, consisted of 12,322 males and 3,678 females.

An estimated 41,400 spottail shiners were transported to Willard Reservoir on 24 May 1982. Live cage samples indicated a hauling mortality of 100% after 24 hours. However, these fish from the live cage samples were handled several hours longer than the rest of the load and this may have caused the total mortality. Personal observation at the time of stocking suggested a survival of about 15%. The sex ratio of a sample of 139 fish was 2.76 males per female. Total length ranged from 82 mm to 128 mm with a mean length of 103.5 mm.

Approximately 27,720 spottail shiners were transported to Willard Reservoir on 4 June 1983. Hauling mortality after 72 hours was 55.5%; an estimated 12,335 live fish were stocked in the reservoir. Sex composition of a sample of 89 fish suggested that about 6,526 males and 5,809 females survived. Total length of fish in the sample ranged from 79 mm to 142 mm with a mean length of 118.2 mm.

Extraneous species (most of which were not found previously in the reservoir) that were inadvertently stocked along with the spottail shiners in 1982 or 1983 included:

Black bullhead (*Ictalurus melas*)
Blacknose dace (*Rhinichthys atratulus*)
Bluntnose minnow (*Pimephales notatus*)
Brook stickleback (*Culaea inconstans*)
Common shiner (*Notropis cornutus*)
Creek chub (*Semotilus atromaculatus*)
Emerald shiner (*Notropis atherinoides*)
Fathead minnow (*Pimephales promelas*)
Hornyhead chub (*Nocomis biguttatus*)
Logperch (*Percina caprodes*)
Longnose dace (*Rhinichthys cataractae*)
Pumkinseed sunfish (*Lepomis gibbosus*)
Sand shiner (*Notropis stramineus*)
Trout-perch (*Percopsis omiscomaycus*)
White sucker (*Catostomus commersoni*)
Yellow perch (*Perca flavescens*)

Numbers of these species stocked were low, but later sampling in the reservoir produced specimens of logperch, common shiners, sand shiners, and hornyhead chubs.

Evidence of spottail shiner reproduction in the reservoir was found all 3 years following stocking. For example, limited sampling in 1981, produced 27 yoy on 8 July, 108 yoy on 15 July, and 20 yoy on 29 July 1981. Mean total lengths of fish on those dates were 30.5, 36.6, and 41.0 mm, respectively. Data from 1982 and 1983 are more detailed and are reported in the section on growth.

Time of spawning of spottail shiners in Willard Reservoir was uncertain. Eighteen spottail shiners collected on 14 April and 29 April 1982 were mature, Age 0+ fish with ripening gonads. No annulus had yet formed. Mean total length was 94.3 mm and the male to female ratio was 3.5:1. Additional adult spottail shiners collected after 16 June 1982 were spawned out and the first annulus had formed on scales. Hence, spawning evidently occurred between 29 April and 16 June 1982. Water temperatures during this time ranged from 9 C to 23 C. It must be noted that the 1982 spottail shiner stocking also took place during this time. Thus, it was not possible to determine if yoy captured during 1982 were the result of spawning by resident spottail shiner or by stocked fish. This same observation was true in 1983. Ripening spottail shiners were collected before the 1983 stocking on 21 and 30

March and on 20 April, and spawned out age I+ fish were collected 28 June, after the stocking of spottail shiners.

Growth. During the summers of 1982 and 1983, total length measurements of yoy spottail shiners were recorded weekly (Table 4). Spottail shiners were found in seine hauls but not in tow net samples. Specimens were first captured in shoreline seine hauls, 21 June 1982 and 28 June 1983. Sampling effort was consistent week to week and the best estimate of relative abundance was the total number captured each week. Sampling effort for a week consisted of approximately 15 seine hauls at nine locations (Figure 2). Numbers of other species captured by each gear along with the spottail shiners are listed in Appendix Tables A, C, and E for 1982 and B, D, and F for 1983.

Growth rate of yoy spottail shiners in Willard Reservoir compared favorably with growth in other areas (Figure 3). The average daily growth increment was 0.74 mm (total length) for the period 21 June to 26 September 1982 (14 weeks) and 0.70 mm for the period 28 June to 18 September 1983 (12 weeks). Water temperatures ranged from 20.5 C to 27.5 C in 1982 and 21.5 C to 29 C in 1983. McCann (1959) found that average daily growth increments for spottail shiners in Clear Lake, Iowa, was 0.52 mm for an 11-week period ending 18 September 1956, 0.69 mm for an 11-week period ending 3 September 1957, and 0.65 mm for a 5-week period ending 25 August 1958. In Lower Red Lake, Minnesota, the average daily growth increments were 0.44 mm for a 9-week period

Table 4. Mean total length (mm) of yoy spottail shiner collected by various gear from Willard Reservoir, 1982 and 1983. (N=total number captured for weekly period)

1982

Week of-	N	Mean	Range	Std. Dev.
6/21	14	17.0	13-20	2.09
/28	12	21.0	18-24	1.79
7/5	9	28.7	26-35	2.60
/12	2	35.0	34-36	0.71
/19	1	34.0	34	0.0
/26	11	42.6	34-52	5.29
8/2	5	54.7	52-60	3.51
/9	4	57.3	54-63	3.97
/16	2	66.0	63-70	4.95
/23	13	71.9	64-78	4.09
/30	8	72.6	66-78	4.46
9/6	10	78.1	71-86	5.78
/13	7	83.0	78-92	4.55
/20	10	84.2	78-89	4.42
/27				
10/4	2	86.0	82-90	5.66

1983

Week of-	N	Mean	Range	Std. Dev.
6/27	1	16.5	16.5	0.0
7/4	8	18.6	14-25	3.95
/11	21	22.3	17-30	3.93
/18	65a	27.5	18-36	3.67
/25	24	35.6	26-42	5.32
8/1	1	33.0	33	0.0
/8	8	44.1	27-49	7.36
/15	17	53.3	39-63	6.30
/22	18	61.9	53-72	5.10
/29	9	68.3	63-73	3.91
9/5	43b	68.5	54-78	6.86
/12	11	72.6	63-84	6.61

a] 42 specimens of this sample were used for mean length estimate.

b] 22 specimens of this sample were used for mean length estimate.

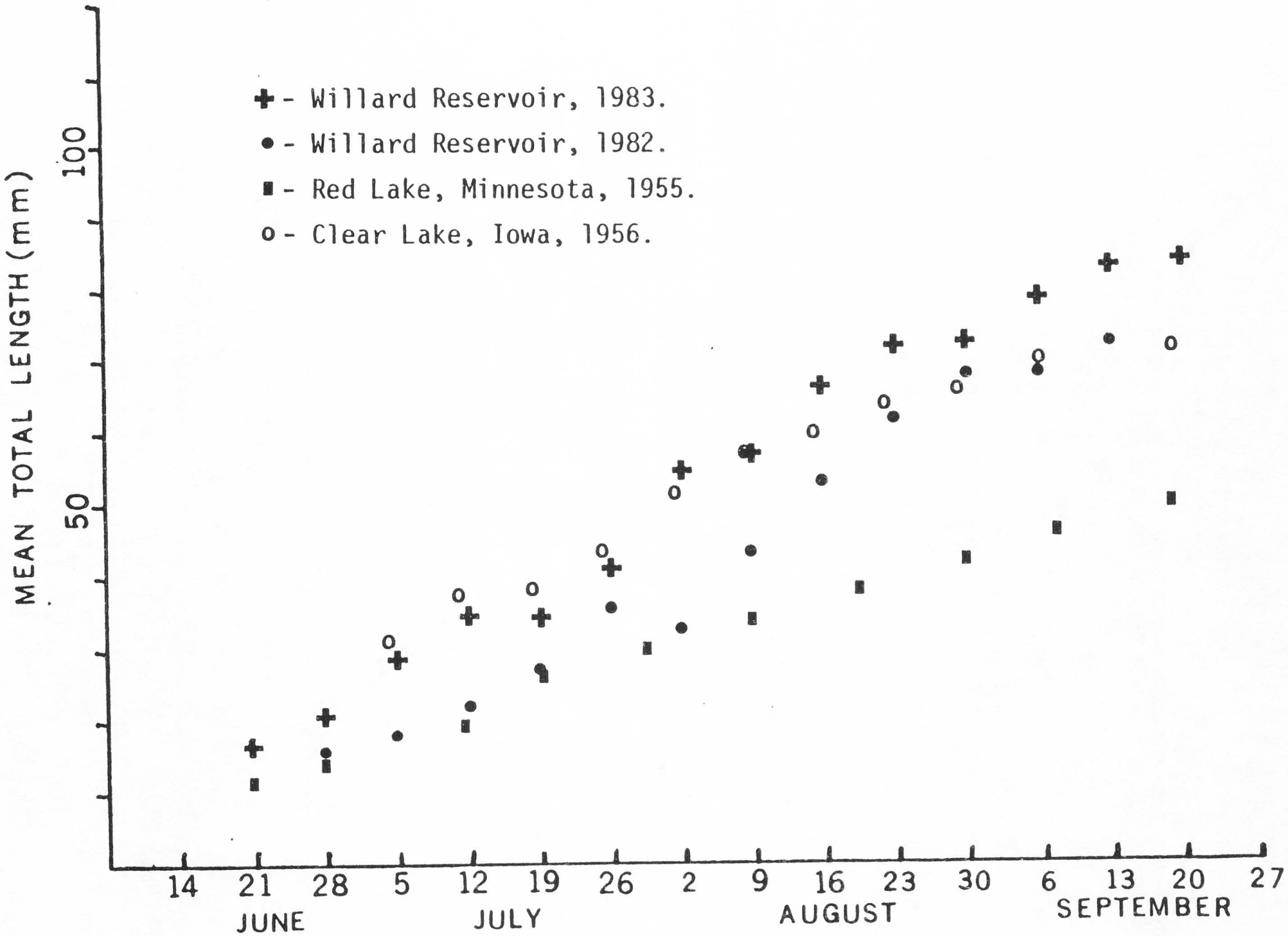


Figure 3. Growth of yoy spottail shiners in Willard Reservoir and other waters.

ending 30 August 1955, 0.30 mm for a 10-week period ending 30 August 1956, and 0.46 mm for an 8-week period ending 30 August 1957 (Smith and Kramer 1964). In general, spottail shiners in Willard Reservoir attained a greater mean length by the end of their first growing season than did fish from other selected waters (Table 5).

Diet. Young-of-the-year spottail shiners in Willard Reservoir fed mainly upon dipterans in 1982 (Table 6). Chironomid larvae and dipteran pupae (Chironomidae and Chaoboridae) were the most frequently ingested organisms and comprised the bulk of the identifiable matter. Cladocerans, Hydracarina (water mites), unidentified insects, vegetation, fish scales, and sand were also found on occasion. No fish were found in stomachs examined. Unidentified matter was often a major component of the stomach contents.

Young-of-the-year and age I and older spottail shiners fed upon much the same organisms in Willard Reservoir in 1982 (Tables 6 and 7). Age I and older spottail shiners fed mainly upon dipterans. Diptera also represented the greatest estimated percent of food organisms by volume (45%) ingested by the fish (Table 7). Chironomid larvae and pupae were the dipterans utilized. Cladocera, mainly Daphnia, were utilized on occasion. Again, unidentified matter was often a major component of the stomach contents. McCann (1959) also reported similar food habits among young and adult spottail shiners in Clear Lake, Iowa. However, Smith and Kramer (1964) found a definite change

Table 5. First-year growth of spottail shiner from selected waters.

Location	Mean TL (mm)	End of Sampling Season
Willard Reservoir, Utah	84	20 September 1982
Willard Reservoir, Utah	73	12 September 1983
Lower Red Lake, Minnesota	50[a]	18 September 1955
Linwood Lake, Minnesota	63	5-17 October 1954
Clear Lake, Iowa	77	27 October 1956
Western Lake Erie, Ohio	74	22-27 October 1959

a] Estimated from growth curve.

Table 6. Stomach contents of yoy spottail shiners, Willard Reservoir, 1982 based on mean number of organisms per stomach. Percentage frequency of occurrence in parenthesis.

Week of-	6/21	6/28	7/5	7/12	7/19	7/26	8/2	8/9	8/16	8/23	8/30	9/6	9/13	9/20	9/27	10/4
Sample size	14	12	9	2	1	11	5	4	2	13	8	10	7	10		2
Mean TL (mm)	17	21	29	35	34	43	55	57	66	72	73	78	83	84		86
Empty (%)	0	0	0	0	0	0	20	0	0	31	38	10	71	30		0
Cladocera	1.4 (21)	0.8 (33)		2.5 (50)		3.3 (55)	2.0 (50)	3.8 (75)			0.2 (20)					7.0 (50)
<u>Daphnia</u>		0.2 (17)					0.8 (25)	0.3 (25)								
Other[a]	1.4 (21)	0.7 (25)		2.5 (50)		3.3 (55)	1.2 (50)	3.5 (50)			0.2 (20)					7.0 (50)
Diptera	1.2 (71)	1.7 (75)	5.1 (100)	1.0 (100)	5.0 (100)	5.6 (91)	5.6 (75)	0.5 (25)	2.0 (100)	3.2 (78)	0.6 (20)	1.1 (22)	4.5 (100)	2.1 (57)		7.0 (100)
Chironomid larvae	1.0 (71)	1.4 (58)	5.1 (100)	0.5 (50)	5.0 (100)	3.1 (91)	5.5 (75)	0.3 (25)	1.5 (100)	2.2 (78)	0.6 (20)	1.1 (22)		1.6 (43)		1.5 (50)
Chaoborid larvae								0.2 (25)		0.2 (11)						
Diptera pupae	0.1 (14)	0.3 (25)		0.5 (50)		2.5 (45)			0.5 (50)	0.8 (33)			4.5 (100)	0.6 (29)		
Diptera adult	0.1 (14)															5.5 (50)
Hydracarina		0.3 (17)					0.3 (25)		0.5 (50)	0.1 (11)						
Amphipoda	0.1 (7)											0.4 (22)				
Unidentified insects	0.1 (14)						1.0 (100)	0.5 (25)		0.2 (22)	0.4 (25)	0.4 (44)	0.5 (50)	0.4 (29)		2.5 (50)
Unidentified matter	(14)		(11)	(50)	(100)	(55)	(75)	(50)		(33)	(40)	(56)	(50)	(57)		
Other[b]			(22)		(100)		(25)			(11)	(40)	(56)		(43)		(50)

a] Includes unidentified cladocera and <u>Bosmina</u>.

b] Includes sand, vegetation, fish scales, and fish eggs.

Table 7. Percentage frequency of occurrence and estimated percentage by volume of food items in age I and older spottail shiner stomachs, Willard Reservoir, 1982[a].

Item	Frequency of Occurrence	Estimated Volume
Diptera	63.6	43.9
Cladocera	33.3	19.5
Copepoda	3.0	0.3
Ostracoda	3.0	3.0
Hydracarina	6.1	0.3
Unidentified insects	27.3	12.9
Fish scales	3.0	(trace)
Vegetation	6.1	(trace)
Unidentified matter	30.3	20.0

a] Based on a sample size of 30 stomachs; 3 additional empty stomachs were not included.

in food selection with an increase in size of spottail shiners in Lower Red Lake, Minnesota. The change became evident at a length of about 70 mm. Chironomids and fish eggs were most frequently ingested by larger spottail shiners and cladocerans most frequently eaten by the smaller fish.

The spottail shiner fed on an equally wide variety of materials in Clear Lake, Iowa (McCann 1959). The most frequently ingested organisms there were dipteran larvae, cladocerans (Bosmina) and Hydracarina. Dipteran adults, tricopteran larvae, grass seeds, and plant fibers were eaten less frequently. Smith and Kramer (1964) determined spottail shiner food habits were related to food availability of both plankton and bottom fauna in Lower Red Lake, Minnesota. In less intensive food habit studies, other workers have reported that spottail shiners frequently feed upon cladocerans, copepods, chironomid larvae, daphnid ephippia, and pollen (Nursall and Pinsent 1969), and Amphipoda and Mysidacea (Anderson and Smith 1971). Stomach contents of spottail shiners from Sugar Creek, Wisconsin, consisted of dipteran and ephemeropteran larvae, spiders, ants, algae and other plant material, debris, and sand (M. Kosmerchock, cited by Becker 1983).

In several instances, spottail shiners from a single seine haul from Willard Reservoir showed considerable variation in food selection. Some of the fish had fed almost entirely on planktonic organisms such as cladocerans while others had fed almost entirely upon bottom-dwelling chironomid larvae. McCann (1959) observed this same mixture of feeding levels in samples of spottail shiners from Clear Lake.

Delta smelt

On 24 March 1982, an estimated 15,000 adult spawning delta smelt were obtained from Butt Creek, a tributary to Butt Valley Reservoir in northern California. A sample of 210 fish had a male to female ratio of 0.87:1 (71:82) with 57 fish of unknown sex. Total length ranged from 93 to 130 mm with a mean length of 110 mm. The fish were stocked in the northeast section of Willard Reservoir. Live cage samples indicated 100% survival after 48 hours and 99% survival after 96 hours. Ripe males and females were removed from the live cages 11 days after stocking.

In addition to the stocking of the ripe delta smelt, freshly fertilized eggs were also obtained from Butt Creek. Two 45.7 x 91.4-cm cheesecloth mats were placed in Butt Creek overnight. When lifted the next day the mats were almost completely covered by a 3-mm layer of eggs. These mats, along with about 2.8 kg of eggs, were transported with the adult delta smelt to Willard Reservoir. They were placed in several locations in Willard Creek, a tributary in the northeast section of the reservoir. Hatching success was not monitored, but mats were void of eggs after 3 weeks.

Evidence of successful hatching was found in the reservoir following stocking. Shoreline seining during June 1982 produced 29 yoy delta smelt. Based upon the fact that the egg mats were void of eggs after 3 weeks and the size of yoy smelt at capture, it is speculated that the captured smelt had been naturally spawned in the reservoir by stocked adults. No additional adult or yoy smelt were captured in the 1982 sampling season.

Overwinter survival of delta smelt was evidenced by the finding of six adult delta smelt in the stomachs of several walleye caught by anglers on 2 April 1983. The smelt (three male and three female) were mature fish in spawning condition. However, no additional specimens were collected during the 1983 sampling season.

Growth. Total length measurements for yoy delta smelt collected in 1982 were recorded by weekly intervals. By the end of June yoy delta smelt had reached 47.5 mm total length (Table 8). Six delta smelt taken from the stomachs of angler-caught walleye in April 1983 were reaching maturity and appeared to be age I fish based on scale examination. Their estimated total length ranged from 100 to 130 mm with a total mean length of 115.7 mm. Hence, first year growth of delta smelt in Willard Reservoir in 1982 approached or exceeded that of delta smelt from Lake Shastina, California (Figure 4). In Lake

Table 8. Mean total length (mm) of yoy delta smelt in Willard Reservoir, 1982 (N=total number captured for sample period).

Week of-	N	Mean	Range	Std. Dev.
5/31	1	27.0	27	0
6/7	10	27.5	23-30	2.12
/14	16	34.0	30-38	2.07
/28	2	47.5	45-50	3.54

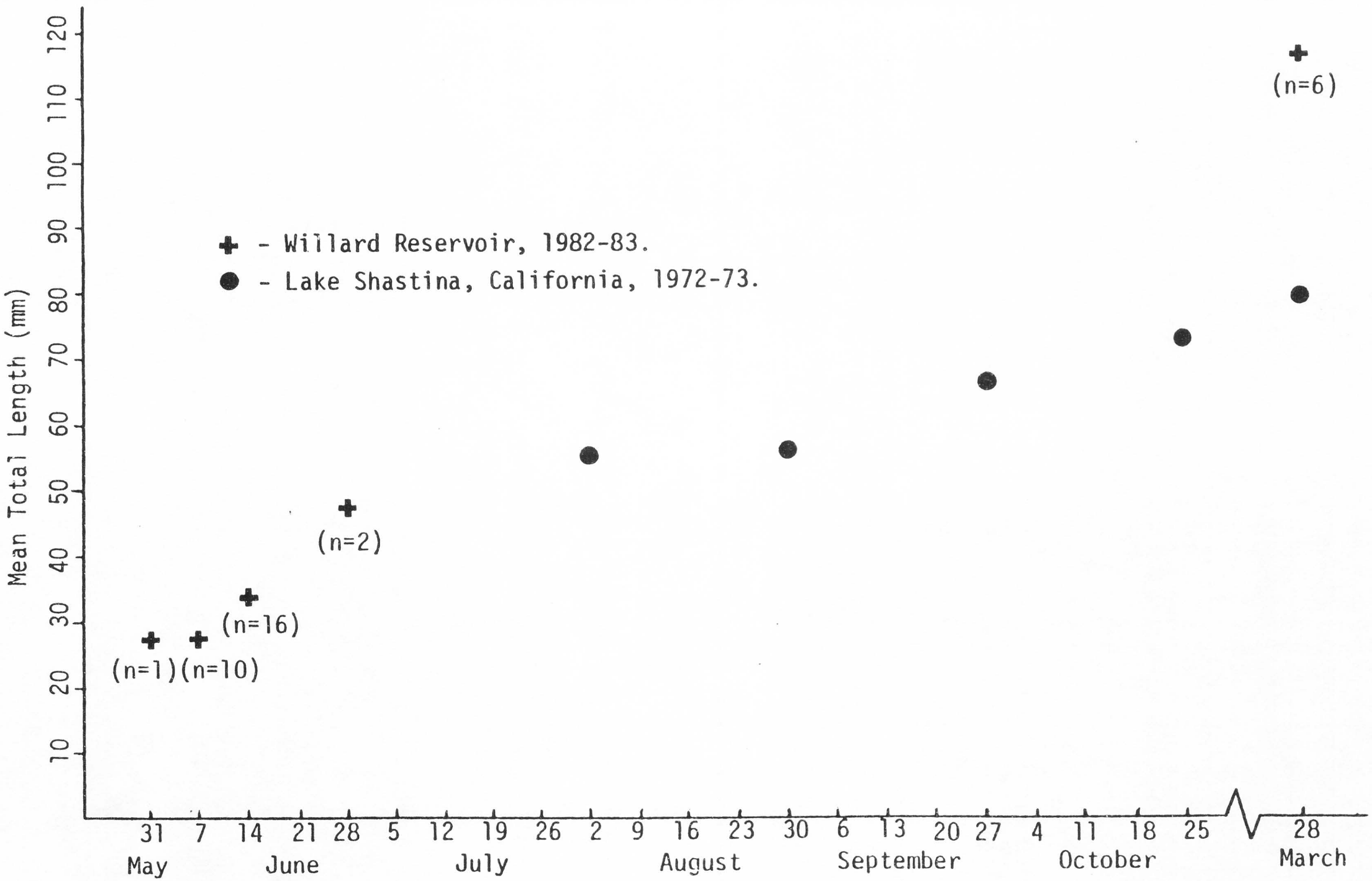


Figure 4. First-year growth of delta smelt in Willard Reservoir and Lake Shastina, California.

Almanor, California, yoy delta smelt had an estimated mean total length of 59 mm (54 mm FL) on 28 August 1974 and 46 mm (42 mm FL) on 27 August 1975 (Hair and Hanson 1976). Mean total length of 10 age I+ gravid females in March 1974 was estimated at 130 mm (119 mm FL); the largest was 139 mm TL (127 mm FL). In Lake Shastina, California, the mean total length of yoy delta smelt was 74 mm (67.3 mm FL) on 24 October 1972 (Wigglesworth 1975). During their first spawning season the mean length was 80 mm TL (72.9 mm FL) and 103 mm TL (93.6 mm FL) in their second spawning season. The longest delta smelt (age II) had a mean length of approximately 118 mm TL (108 mm FL) (Wigglesworth 1975). Delta smelt reportedly reach 135 mm standard length (McAllister 1963), which, based on measurement of 30 fish in the laboratory, represents 166 mm total length.

Diet. Young-of-the-year delta smelt in Willard Reservoir fed mainly upon zooplankton, especially copepods, during June 1982 (Table 9). The copepod *Diaptomus* was found in 28 of 29 stomachs examined and comprised the greatest number of organisms found in the stomachs. Copepod nauplii (20 of 29 stomachs) and *Cyclops* (18 of 29 stomachs) were also found on occasion and generally in lesser numbers than *Diaptomus*. Cladocerans, the other major food organism utilized, were found in 19 of the 29 stomachs. Dipteran larvae and pupae were also ingested by larger delta smelt in later June. Fish were not found in delta smelt stomachs. Delta smelt in Lake Shastina fed upon much the same organisms as those in Willard Reservoir. Cladocerans, copepods,

Table 9. Stomach contents of yoy delta smelt, Willard Reservoir, 1982 based on mean number of organisms per stomach. Percentage frequency of occurrence in parenthesis.

Week of-	5/31	6/7	6/14	6/21	6/28
Sample size	1	10	16		2
Mean TL (mm)	28	28	35		48
Cladocera		0.2 (20)	24.9 (94)		118.5 (100)
Daphnia					12.5 (50)
Other[a]		0.2 (20)	24.9 (94)		106.0 (100)
Copepoda	19.0 (100)	41.1 (100)	97.2 (100)		441.0 (100)
Cyclops	1.0 (100)	.5 (50)	5.1 (69)		31.0 (50)
Diaptomus	18.0 (100)	19.4 90)	64.8 (100)		410.0 (100)
nauplii		20.2 (50)	27.3 (94)		
Diptera		0.1 (10)			4.5 (100)
Chironomid larvae					1.5 (50)
Chaoborid larvae		0.1 (10)			1.0 (100)
Diptera pupae					2.0 (100)

a] Includes unidentified cladocerans and *Bosmina*.

and chironomid pupae were found in 78%, 50%, and 42%, respectively, of delta smelt stomachs from Lake Shastina (Wigglesworth 1975). Other food items included chironomid larvae, chaoborid larvae, and smelt eggs. In Lake Almanor, the cladoceran *Daphnia* was the most important food item eaten by delta smelt, followed by ostracods, copepods, dipteran larvae, and amphipods (Hair and Hanson 1976).

Diet Similarities Among Species

A comparison of food habits was attempted among yoy spottail shiners, delta smelt, walleye, and black crappie collected in 1982. Comparison of stomach contents among the four species was limited because in no single week were all four species collected together (Appendix Tables A-F). Hence, data were combined over capture methods. Even then, statistical analysis of data was not appropriate.

Walleye yoy were collected first on 29 April and consistently thereafter until the end of the sampling season in early October. Delta smelt yoy were collected beginning 3 June and only during the month of June 1982. Spottail shiner yoy were first collected 21 June and in variable numbers throughout the 1982 sampling season. Crappie yoy appeared in collections beginning 6 July and throughout the rest of the 1982 sampling season. Hence, only walleye and delta smelt diets could be compared during June, and diets of walleye, crappie, and spottail shiners during July, August, and September.

Walleye yoy containing food in Willard Reservoir were first found at a total length of approximately 9.5 mm (3 May 1982). First food items ingested were copepods and cladocerans (Table 10). These were the main organisms utilized until early June when larval carp entered the diet. Larval carp and dipterans were eaten most frequently during

Table 10. Stomach contents of yoy walleye, Willard Reservoir, 1982 based on mean number of organisms per stomach. Percentage frequency of occurrence in parenthesis.

Week of-	4/26	5/3	5/10	5/17	5/24	5/31	6/7	6/14	6/21	6/28	7/5	7/12	7/19	7/26	8/2	8/9	8/16	8/23	8/30	9/6	9/13	9/20	9/27	10/4
Sample size	12	16	5	4	1	5	24	32	20	7	2	24	20	11	8	9	20	20	21	9	12	9	21	1
Mean TL (mm)	8	9	10	12	14	23	28	32	40	49	63	65	83	92	100	107	118	135	139	157	150	160	162	137
Empty (%)	100	81	0	0	0	0	0	0	0	14	0	17	15	0	0	0	5	0	0	33	17	22	5	0
Cladocera		2 (67)	3 (80)	4 (100)	14 (100)	10 (60)	3 (25)	4 (44)	6 (25)	2 (50)	71 (100)	67 (80)	62 (94)	141 (73)	257 (88)	184 (78)	145 (79)	18 (15)	215 (71)	105 (33)	5 (20)	22 (29)	76 (20)	
<u>Daphnia</u>		1 (67)	2 (60)	1 (75)	1 (100)	1 (20)		1 (6)	1 (10)		37 (100)	59 (80)	59 (94)	127 (64)	240 (75)	184 (78)	145 (79)	18 (15)	215 (71)	105 (33)		17 (29)	74 (20)	
Other[a]		1 (33)	1 (40)	2 (50)	13 (100)	10 (60)	3 (25)	4 (41)	5 (20)	2 (50)	34 (100)	8 (25)	3 (35)	14 (64)	17 (63)						5 (20)	5 (14)	1 (10)	
Copepoda		1 (33)	4 (100)	9 (75)	8 (100)	1 (40)	8 (71)	5 (50)	6 (50)	2 (50)	46 (50)	1 (15)	1 (12)		1 (13)									
<u>Cyclops</u>			3 (100)	2 (75)			1 (4)	2 (22)	4 (50)	2 (33)			1 (6)											
<u>Diaptomus</u>				7 (50)	8 (100)	1 (40)	8 (71)	4 (38)	2 (20)	1 (17)	46 (50)	1 (15)	1 (6)		1 (13)									
Diptera							1 (25)	2 (69)	1 (60)	1 (67)	1 (50)	6 (55)	3 (71)	5 (55)	25 (100)	95 (78)	1 (42)	2 (35)	1 (38)	1 (33)	1 (30)		1 (25)	
Chironomid larvae							1 (13)	1 (25)	1 (40)	1 (17)		1 (15)	1 (41)	1 (27)	5 (75)	2 (22)	1 (16)	1 (15)	1 (5)	1 (17)	1 (10)		1 (5)	
Chaoborid larvae							1 (13)	1 (47)	1 (20)		1 (50)	3 (25)	1 (29)	3 (27)	16 (75)	22 (78)	1 (32)							
Diptera pupae							1 (10)	1 (3)	1 (30)	1 (67)	1 (50)	3 (50)	1 (41)	1 (45)	3 (50)	71 (78)	1 (16)	2 (30)	1 (33)	1 (17)	1 (20)		1 (25)	
Fish						1 (60)	3 (50)	3 (66)	3 (80)	1 (67)	1 (50)	1 (5)		1 (36)		1 (22)	1 (42)	2 (90)	1 (52)	1 (50)	1 (80)	1 (71)	2 (95)	5 (100)
Carp						1 (60)	3 (50)	3 (66)	3 (80)	1 (67)				1 (27)		1 (11)	1 (5)	1 (15)					1 (5)	
Green sunfish																	1 (21)	1 (50)	1 (24)	1 (17)	1 (50)	1 (43)	1 (50)	
Bluegill																		1 (20)		1 (17)			1 (25)	1 (100)
Unidentified[b]											1 (50)	1 (5)		1 (27)		1 (11)	1 (21)	1 (50)	1 (29)	1 (33)	1 (60)	1 (43)	1 (75)	4 (100)

a] Includes unidentified cladocerans, <u>Bosmina</u>, <u>Ceriodaphnia</u>, and <u>Diaphanosoma</u>.

b] Includes 1 spottail shiner during the week of 8/9.

June with cladocerans and copepods ingested less frequently. In July, cladocerans and dipterans were the main food items. Dipterans, mainly chaoborid larvae, and cladocerans, mainly *Daphnia*, were ingested most frequently in early August. Fish, especially young centrarchids, entered the diet in mid-August and were the most frequently eaten organisms thereafter. Cladocerans (*Daphnia*) were utilized in quantity on occasion during the mid-August to late September period. Copepodids, copepod nauplii, ephemeropterans, and unidentified insects were found on occasion in small quantities and were not included in Table 10.

Black crappie yoy in Willard Reservoir fed mainly upon cladocerans and copepods during 1982 (Table 11). Smaller unidentified cladocerans (most suspected as *Bosmina*) were ingested in greater numbers than the larger *Daphnia*. Copepods utilized were *Diaptomus* and *Cyclops* with *Diaptomus* generally eaten more frequently and in greater numbers. Dipterans, especially chaoborid larvae, were a major part of the stomach contents at times. Only two fish were found in the crappie stomachs examined, a carp in late July and a green sunfish in late September.

In June, yoy delta smelt fed almost exclusively upon copepods mainly *Diaptomus* and occasionally *Cyclops*. Cladocerans and dipterans were eaten in lesser amounts (Figure 5). Walleye yoy fed mainly upon

Table 11. Stomach contents of yoy black crappie, Willard Reservoir, 1982 based on mean number of organisms per stomach. Percentage frequency of occurrence in parenthesis.

Week of-	7/5	7/12	7/19	7/26	8/2	8/9	8/16	8/23	8/30	9/6	9/13	9/20	9/27	10/4
Sample Size	5	8	10	2	10	8	10	10	10	10	10	20	6	2
Mean TL (mm)	15	22	35	43	52	58	57	61	68	70	74	82	79	92
Cladocera	7.2 (100)	3.8 (75)	43.2 (100)	298.5 (100)	278.3 (100)	415.9 (100)	75.5 (100)	153.4 (100)	89.7 (100)	218.1 (100)	241.7 (100)	127.0 (100)	4.0 (50)	135.0 (100)
Daphnia			4.6 (70)	10.0 (100)	59.0 (100)	86.4 (88)	38.4 (100)	29.1 (100)	29.3 (100)	12.1 (100)	32.3 (50)			
Other[b]	7.2 (100)	3.8 (75)	38.6 (100)	288.5 (100)	219.3 (100)	329.5 (75)	37.1 (100)	124.3 (100)	60.4 (100)	206.0 (100)	209.4 (100)			
Copepoda	26.8 (100)	35.5 (100)	84.2 (100)	52.5 (100)	143.3 (100)	23.5 (88)	76.2 (100)	97.0 (100)	79.0 (90)	190.7 (100)	135.6 (100)	131.2 (100)	5.5 (75)	420.0 (100)
Cyclops	13.8 (80)	7.1 (75)	27.6 (80)	30.0 (100)	15.0 (100)	18.1 (63)	0.7 (50)	4.6 (60)	12.1 (70)	168.2 (100)				
Diaptomus	13.0 (100)	28.4 (88)	56.6 (70)	22.5 (100)	128.3 (90)	5.4 (63)	75.5 (100)	92.4 (100)	66.9 (90)	22.5 (100)				
Diptera		0.4 (25)	3.0 (80)	1.5 (50)	25.0 (100)	16.4 (88)	1.1 (30)	0.4 (30)	2.5 (80)	27.4 (70)	2.9 (70)	1.9 (75)	0.3 (25)	1.5 (100)
Chironomid larvae			0.2 (20)			0.6 (25)	0.4 (20)	0.4 (30)	1.3 (60)	0.8 (20)	0.4 (30)	0.5 (40)	0.3 (25)	
Chaoborid larvae		0.4 (25)	2.7 (70)	1.5 (50)	25.0 (100)	14.8 (88)	0.1 (10)		0.4 (20)	26.6 (70)	1.8 (30)	0.2 (5)		
Diptera pupae			0.1 (10)			1.0 (25)	0.6 (20)		0.8 (50)		0.7 (50)	1.2 (55)		1.5 (100)
Fish[c]				0.5 (50)									0.3 (25)	

a] Based on stomachs containing food. All stomachs contained food except 2 collected the week of 9/27.

b] Includes mainly *Bosmina* and unidentified cladocera, some *Ceriodaphnia* and *Diaphanosoma*.

c] Fish scales were also ingested on occasion but were not included in the table.

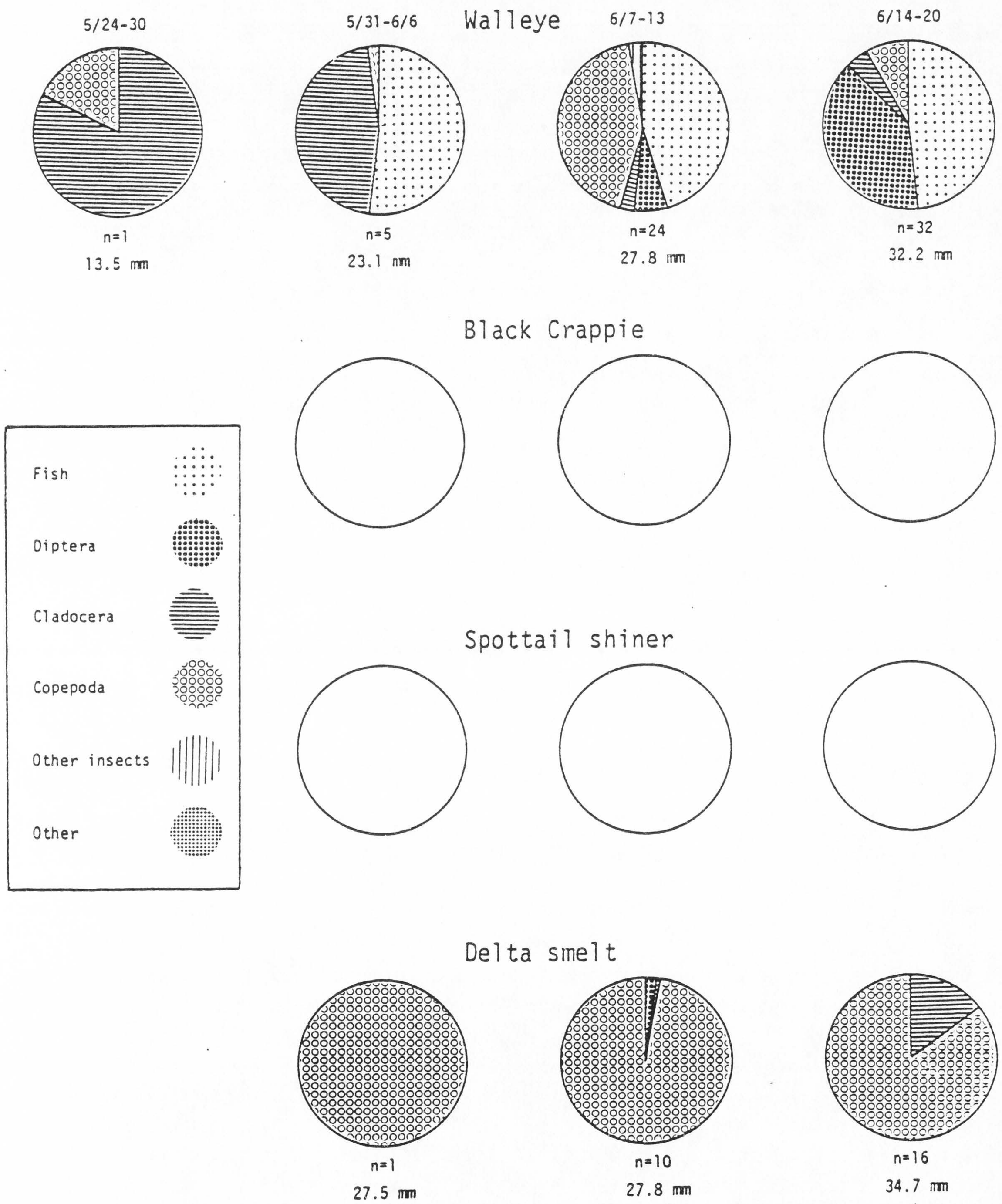
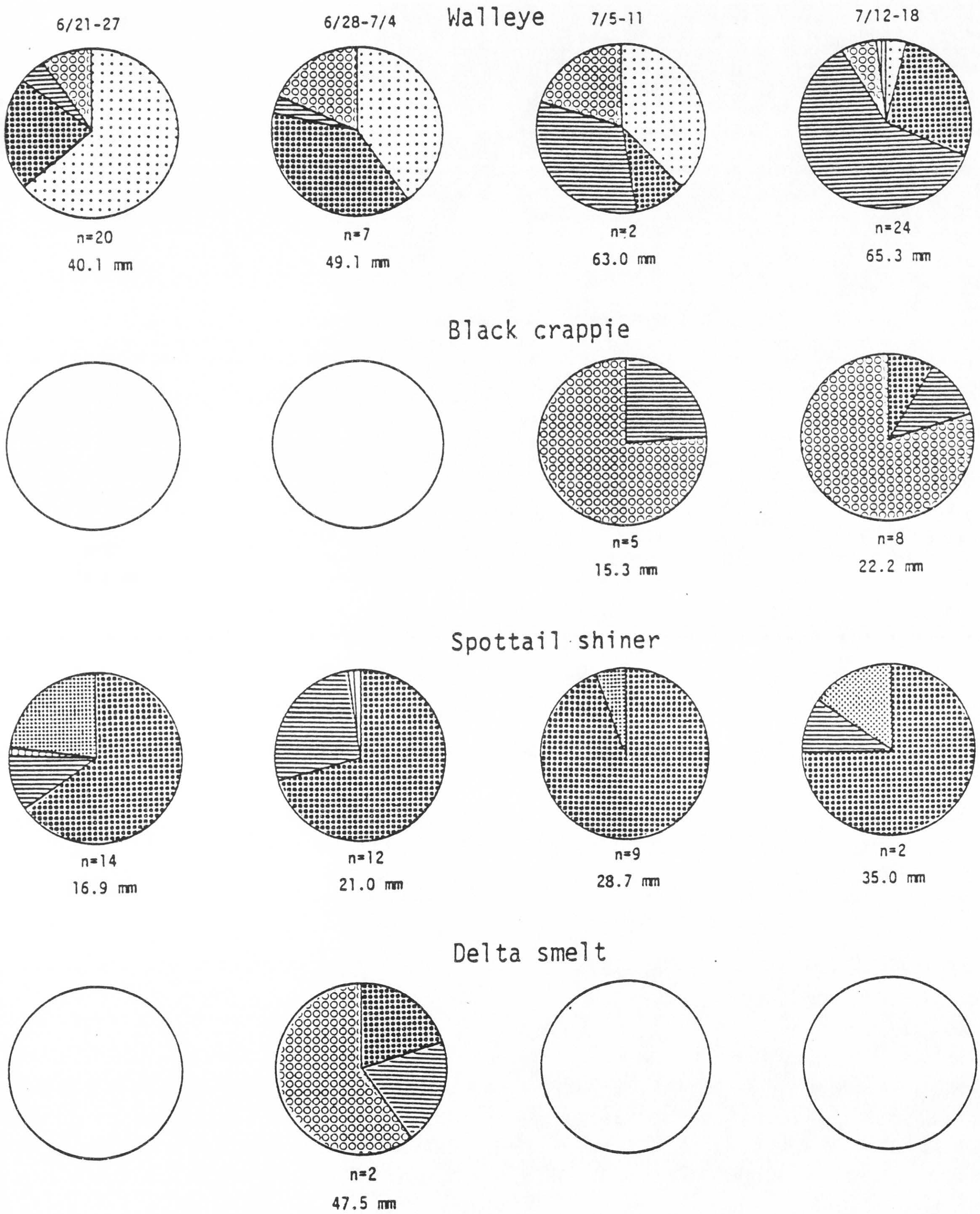


Figure 5. Estimated percentage of food items by volume in yoy fish stomachs, Willard Reservoir, 1982.



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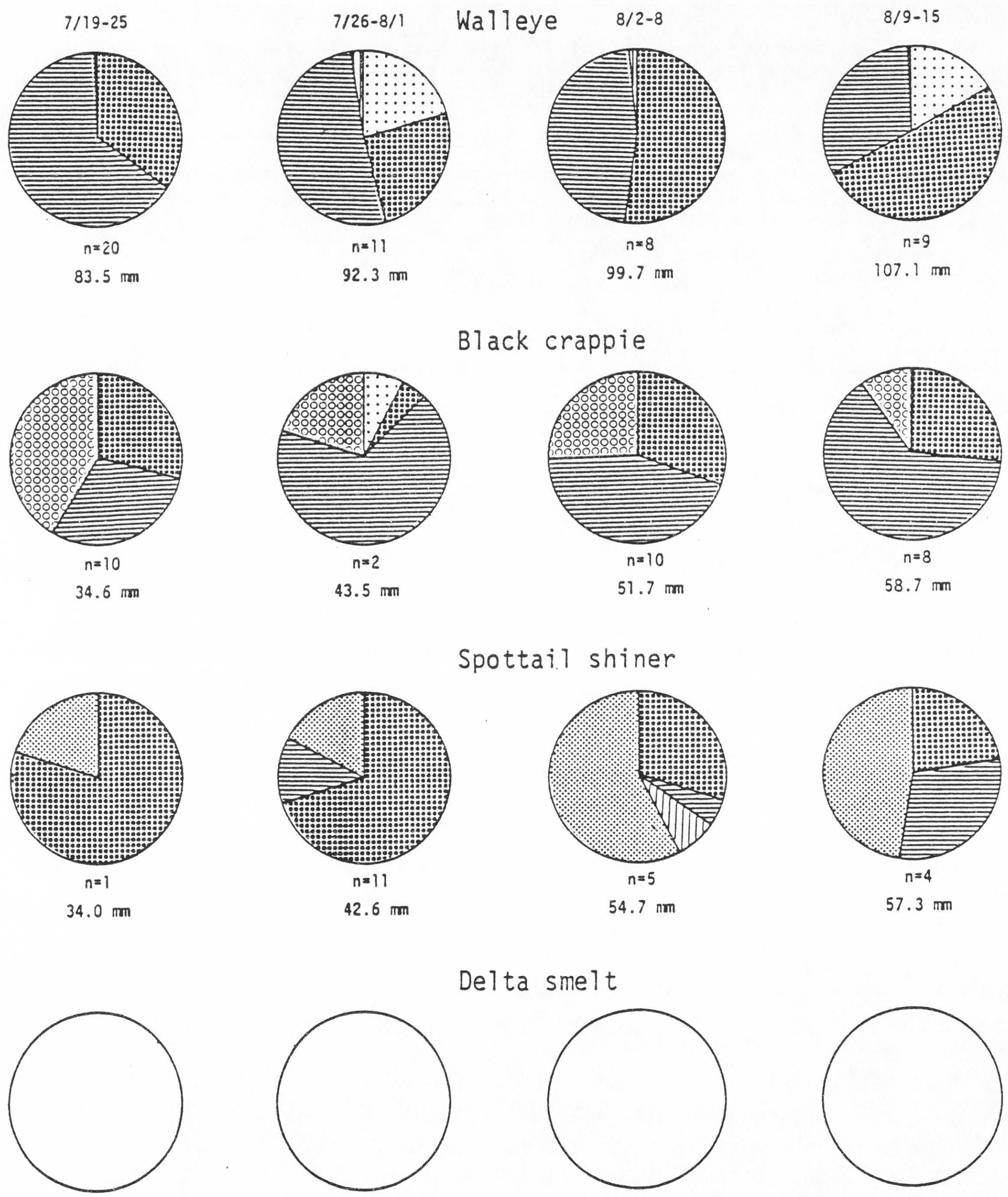

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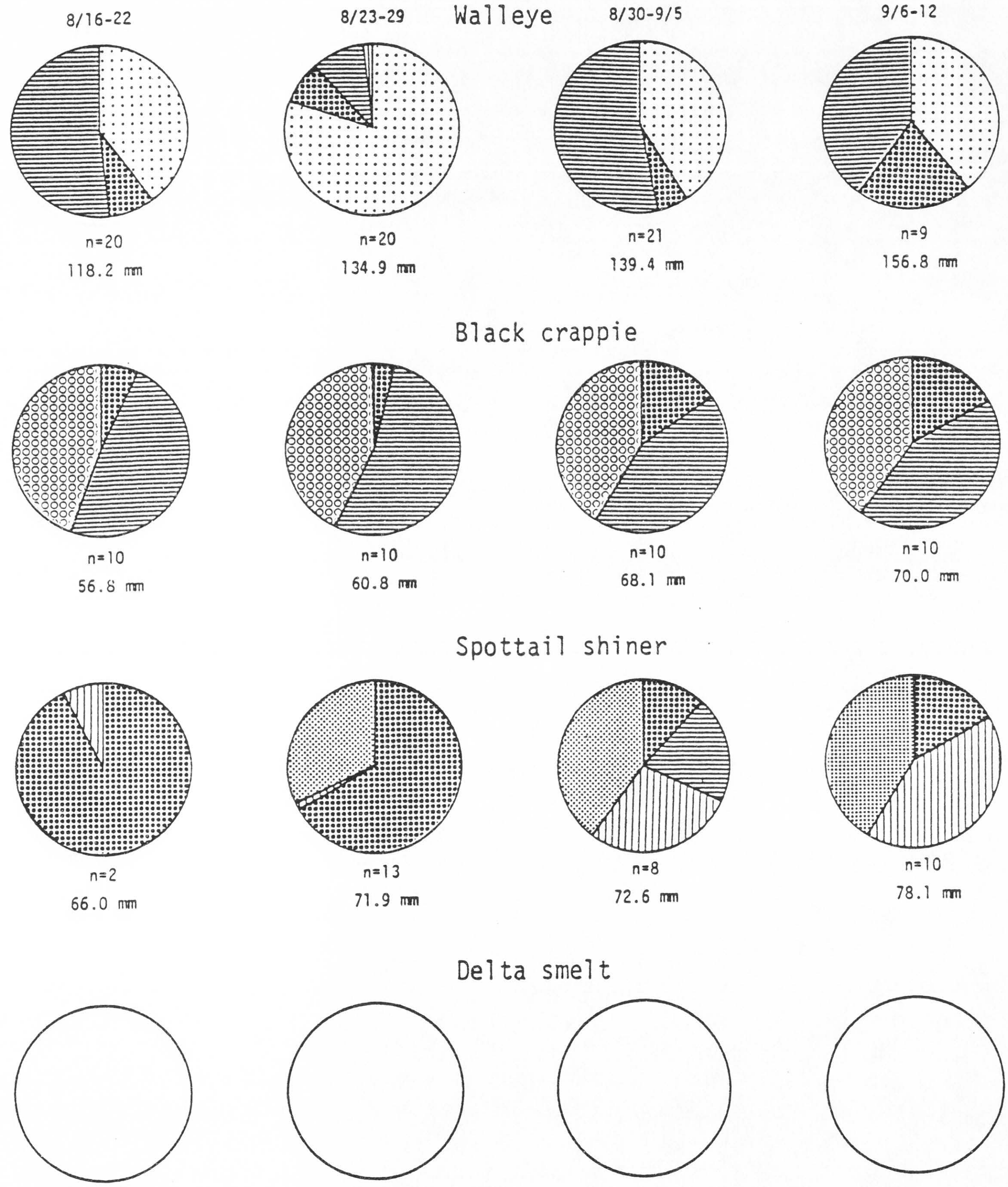

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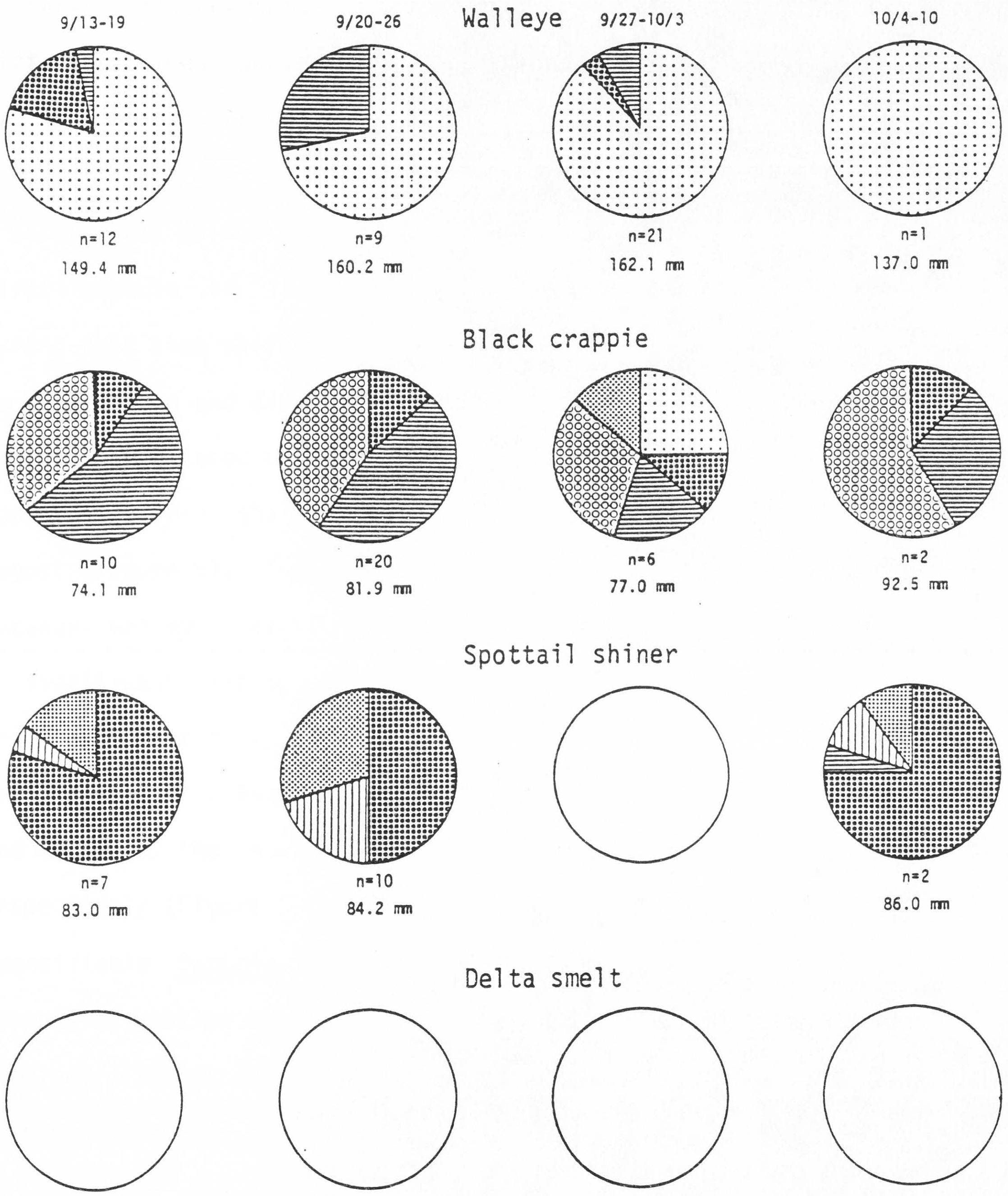

Figure 5. (continued)

fish, namely larval carp which were in abundance at that time. Dipterans, cladocerans, and copepods contributed varying amounts at different times during June (Figure 5). No appreciable diet overlap was evident between walleye and delta smelt during June.

Spottail shiner yoy fed mainly upon dipterans from the time of first capture in late June until early August (Figure 5). Walleye during this time shifted from larval carp in late June and early July to cladocerans and dipterans in late July and early August (Figure 5). Crappie yoy entered the collections in early July and fed mainly upon copepods before shifting to cladocerans and some dipterans in early August (Figure 5). Again, no appreciable diet overlap was evident between walleye, crappie, and spottail shiner yoy during this time. If significant overlap of food items did seem evident, it usually involved different species within the major food group. For instance, for the week of 2 August 1982, cladocerans comprised an estimated 47% and 44% of the volume of food ingested by walleye and crappie, respectively (Figure 5). However, walleye had fed upon the larger identifiable *Daphnia* (> 1.5 mm) whereas crappie had utilized greater amounts of smaller unidentified cladocerans (< 1 mm, most suspected as *Bosmina*) (Tables 10 and 11). This same observation held true for the dipteran category. For the week of 9 August 1982, dipterans comprised an estimated 51%, 27%, and 23% of the volume of food ingested by walleye, crappie, and spottail shiner, respectively (Figure 5).

Walleye yoy fed mainly upon dipteran pupae, crappie yoy upon chaoborid larvae, and spottail shiner upon chironomid larvae (Tables 6, 10, and 11).

By mid-August, walleye were feeding almost exclusively upon fish, mainly green sunfish and bluegill which were in abundance at the time. Cladocerans (mainly Daphnia >1.5 mm) contributed an appreciable amount on occasion (Figure 5). Spottail shiner yoy continued to rely upon dipterans while crappie utilized mainly cladocerans (most smaller unidentified taxa such as Bosmina) and copepods (Figure 5). Again, no significant overlap of food organisms was evident. Mean lengths of invertebrates ingested that were measureable are listed in Appendix Table Q.

Diet-overlap indexes were considered as another method of comparing the yoy diets. Wallace (1981) evaluated several published diet-overlap indexes and found the Schoener index (Schoener 1970) based upon the average of volume percentages to be the most satisfactory. Schoener index values based upon the mean estimated volume percentages were calculated for yoy walleye, black crappie, delta smelt, and spottail shiner (Table 12). The yoy diets were grouped into monthly periods for the Schoener index calculations. Overlap in the index is considered biologically significant when the value exceeds 0.60 (Wallace 1981). No values calculated between the

Table 12. Schoener diet-overlap values for yoy walleye, delta smelt, spottail shiner, and black crappie, Willard Reservoir, Utah, 1982.[a]

	June 5/31-6/27	July 6/28-8/1	August 8/2-8/29	September 8/30-10/3
Walleye vs delta smelt	0.26			
Walleye vs spottail shiner	0.30	0.44	0.30	0.12
Walleye vs black crappie		0.46	0.50	0.36
Spottail shiner vs black crappie		0.29	0.24	0.19

[a]Values calculated according to Schoener (1970) based upon the mean of estimated volume percentages.

four yoy fish species exceeded this 0.60 value (Table 12). Thus, based upon the Schoener index, no significant diet overlap existed between yoy walleye, black crappie, delta smelt, and spottail shiner collected from Willard Reservoir in 1982.

Diet of age I and older spottail shiner was similar to yoy diet as previously stated and no appreciable diet overlap between yoy walleye, crappie, and delta smelt was evident in 1982. Utilization of similar foods between age I and older spottail shiner and age I and older crappie was also determined for 1982. Data on spottail shiner diet were grouped into monthly periods corresponding to crappie samples (Table 13) and compared. April and August were the two months considered comparable, and food habits were generally dissimilar. Crappie fed mainly upon cladocerans in April and August - an estimated 74% and 50% of the food volume ingested, respectively (Figure 6). Dipterans contributed about 31% of the food volume in August and corixids an estimated 48% in July (Figure 6). Age I and older spottail shiners fed mainly upon dipterans in both April and August, about 47% and 56% of the food volume, respectively (Figure 7). Cladocerans comprised 30% of the food volume in April; unidentified matter was 39% in August.

Table 13. Stomach contents of age I and older spottail shiners, Willard Reservoir, 1982 based on mean number of organisms per stomach. Percentage frequency of occurrence in parenthesis.

	April	June	July	August	September
Sample size	18	3	5	8	2
Mean TL (mm)	94	95	100	109	112
Empty (%)	0	33	0	13	50
Cladocera	27.8 (44)		18.4 (40)	0.3 (14)	
Daphnia	24.4 (39)		17.8 (20)	0.3 (14)	
Other[a]	3.4 (11)		0.6 (20)		
Diptera	2.7 (67)	0.5 (50)	1.6 (60)	5.5 (71)	
Chironomid larvae	0.6 (33)	0.5 (50)	0.8 (40)	2.1 (29)	
Diptera pupae	2.1 (44)		0.8 (40)	3.4 (71)	
Other insects[b]	0.1 (6)			1.0 (57)	13.0 (100)
Other[c]	(33)	(50)	(80)	(71)	

a] Includes unidentified cladocerans and Bosmina.

b] Includes Hydracarina, unidentified insects, and ostracods.

c] Includes unidentified matter, vegetation, and fish scales.

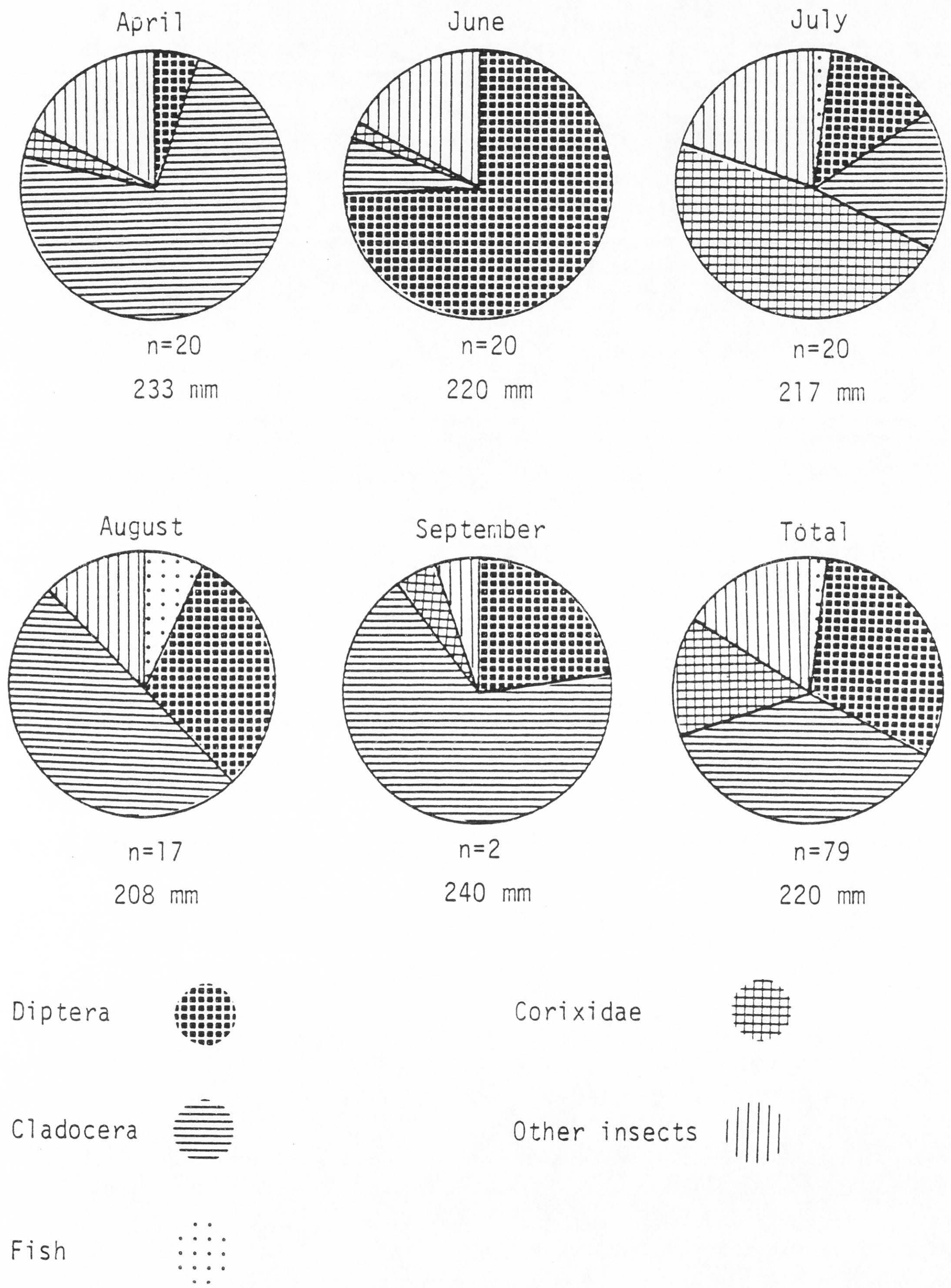

Figure 6. Estimated percentage of food items by volume in age I and older black crappie stomachs, Willard Reservoir, 1982.

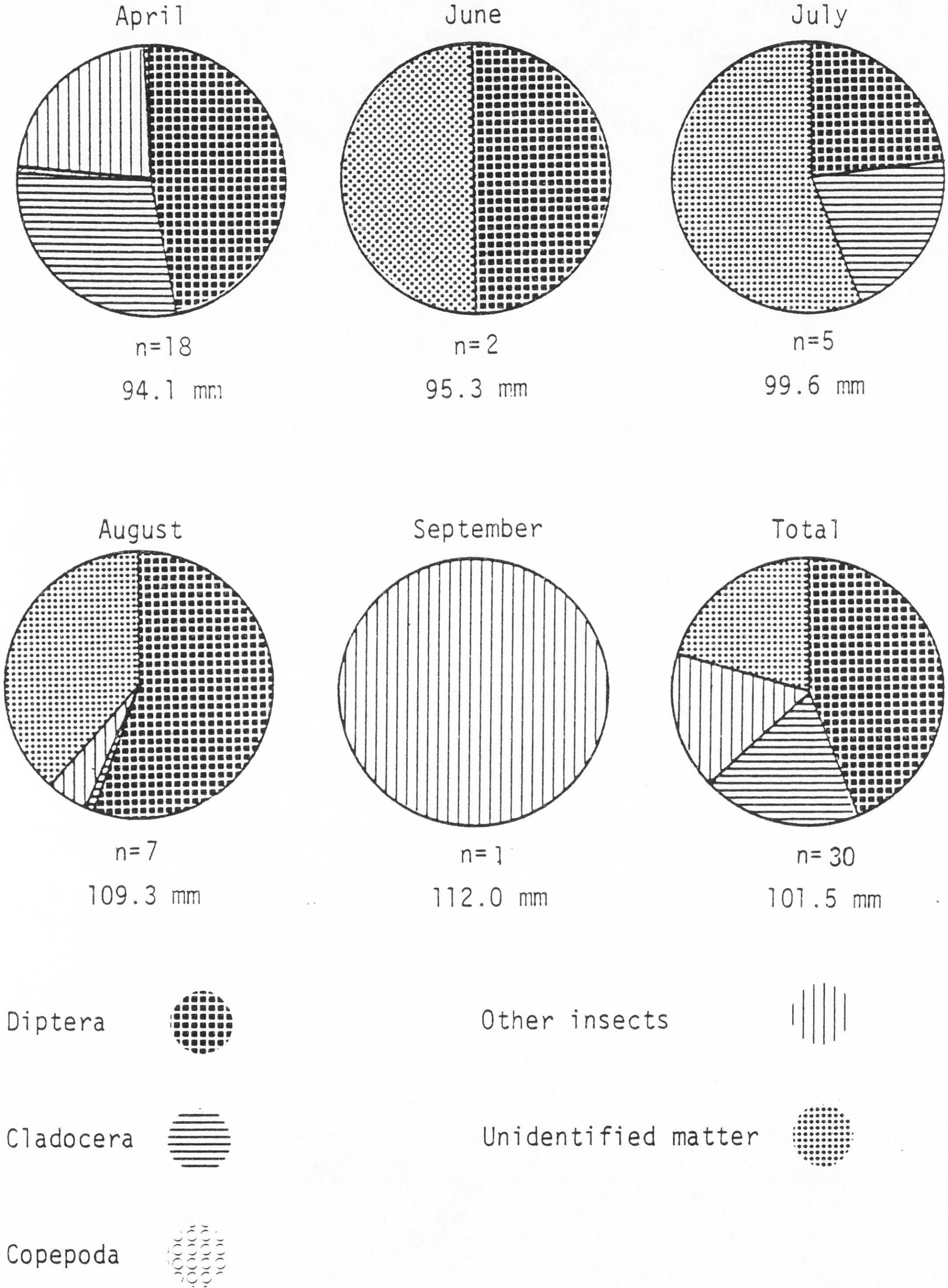

Figure 7. Estimated percentage of food items by volume in age I and older spottail shiner stomachs, Willard Reservoir, 1982.

First-Year Growth in Willard Reservoir

Walleye in Willard Reservoir exhibited good growth in their first year of life. Walleye yoy reached a mean total length of 162 mm by 1 October 1982 and 166 mm by 1 September 1983 (Table 14). Empirical lengths at the end of the first growing season were not available for the years before forage introductions in Willard Reservoir. Young-of-the-year walleye averaged 137 mm TL by late October 1962 in Lake Winnebago, Wisconsin (Priegel 1969), 131 mm by 30 August 1953 in Red Lakes, Minnesota (Smith and Pycha 1960), 167 mm TL by 13 September 1973 in a South Dakota prairie pothole (Walker and Applegate 1976), and averaged 185 mm TL by the end of August for the years 1963-1968 in Lake Erie (Wolfert 1977).

Data collected in the 1973 and 1976 growing season by the Utah Division of Wildlife Resources suggested yoy walleye growth at points during the first year of life comparable with that found in my study. Walleye yoy collected on 3 July and 18 July 1973 had mean total lengths of 63.9 mm (n=12) and 81.3 mm (n=6), respectively (J. Leppink, Utah Division of Wildlife Resources, personal communication). In comparison, yoy walleye collected 6-8 July and 19-22 July 1982 had mean total lengths of 63.0 mm and 83.5 mm, respectively (Table 14), very similar to those of 1973. Walleye yoy collected 1 July 1976 had a mean total length of 56.1 mm (n=39) which was significantly larger

Table 14. Mean total length (mm) of yoy walleye collected by various gear from Willard Reservoir, 1982 and 1983. (N=sample size)

1982

Week of-	N	Mean	Range	Std. Dev.
4/26	12	7.8	7-8	0.24
5/3	16	8.9	9-10	0.35
/10	5	10.1	10-11	0.42
/17	4	12.1	12-13	0.63
/24	1	13.5	13.5	0
/31	5	23.1	20-26	2.46
6/7	24	27.8	24-32	2.02
/14	32	32.2	25-36	2.46
/21	25	39.4	32-48	3.71
/28	7	49.1	42-57	4.95
7/5	2	63.0	56-70	9.90
/12	31	67.8	56-75	4.27
/19	33	83.5	74-100	6.02
/26	11	92.3	79-122	11.89
8/2	8	99.8	93-107	4.64
/9	11	107.1	100-116	5.42
/16	23	118.2	96-131	9.01
/23	26	134.9	122-178	12.33
/30	23	139.4	110-191	15.22
9/6	9	156.8	141-172	10.73
/13	12	149.4	96-180	22.55
/20	9	160.2	131-183	16.63
/27	21	162.1	140-177	9.64
10/4	1	137.0	137	0

1983

Week of-	N	Mean	Range	Std. Dev.
7/4	4	56.5	54-60	2.65
/11	12	63.6	54-72	5.17
/18	4	76.5	72-84	5.43
/25				
8/1				
/8	1	102.5	102.5	0
/15				
/22	3	138.7	130-145	7.77
/29	6	164.0	149-183	11.93
9/5	1	151.0	151	0

($P \leq 0.05$) than the average length (49.1 mm) of walleye collected 28 June 1982 (Table 14).

Available data on yoy black crappie in Willard Reservoir collected in 1976 by the Utah Division of Wildlife Resources indicated sizes comparable with yoy crappie in my study. Total length of yoy black crappie was 37.3 mm (n=537) on 26 July 1976 (J. Leppink, Utah Division of Wildlife Resources, personal communication) in comparison to 42.5 mm TL on 28 July 1982 and 47.0 mm TL during 26-29 July 1983 (Table 15). Young-of-the-year black crappie reached a mean total length of 92.5 mm by 4 October 1982 and 97.8 mm by 13 October 1983 (Table 15). Again, no empirical lengths at the end of the growing season for yoy crappie in Willard Reservoir were available for the years previous to this study. Carlander (1977) lists empirical total lengths for age 0 black crappie in October as 72 mm in Iowa, 81 mm in Tennessee, 135 mm in Oklahoma, 190 mm in Louisiana, and an overall mean total length of 106 mm.

Body length measurements of channel catfish, green sunfish, bluegill, and carp were also determined (Appendix Tables G-K). Green sunfish and bluegill were difficult to differentiate until they had reached a total length of about 15-20 mm. Hence, a separate table for *Lepomis* sp. was prepared (Appendix Table J). First-year growth was compared for walleye, delta smelt, spottail shiner, crappie, and

Table 15. Mean total length (mm) of yoy black crappie collected by various gear from Willard Reservoir, 1982 and 1983. (N=sample size)

1982

Week of-	N	Mean	Range	Std. Dev.
7/5	5	15.1	13-17	1.52
/12	8	22.1	19-29	2.83
/19	68	28.6	17-43	6.70
/26	2	42.5	35-51	10.60
8/2	40	46.9	34-59	5.85
/9	8	58.3	49-66	5.86
/16	60	56.9	43-69	6.20
/23	40	62.6	52-80	6.39
/30	66	72.7	24-97	13.64
9/6	35	65.0	34-94	13.00
/13	46	79.7	48-102	10.85
/20	53	72.7	35-111	21.08
/27	6	77.0	46-95	17.37
10/4	2	92.5	84-101	12.02

1983

Week of-	N	Mean	Range	Std. Dev.
6/6	2	7.3	6-9	1.77
/13	23	9.5	6-12	1.55
/20	8	14.1	14-15	0.52
/27	100	18.6	14-24	1.96
7/4	104	24.9	9-28	2.06
/11	78	30.2	19-37	2.92
/18	72	37.9	19-44	4.37
/25	73	47.0	22-54	4.83
8/1	30	52.6	46-61	3.92
/8	60	52.6	20-66	12.97
/15	30	45.1	31-65	7.10
/22	18	68.8	41-87	14.48
/29	19	62.2	32-97	22.27
9/5	24	55.3	32-104	17.14
/12	30	58.2	39-97	20.41
/19				
/26				
10/3				
/10	21	97.8	49-110	14.92

channel catfish to show relative sizes between species at different times of the year (Appendix Figures A and B). Inasmuch as these data were not part of the forage fish evaluation, they are included in the appendices for reference.

Utilization of Introduced Forage Species

Walleye

Utilization of spottail shiners and delta smelt by age I and older walleye was determined by examining the stomach contents of 77 walleye sampled in 1982 and 54 walleye sampled in 1983 from Willard Reservoir. Spottail shiners were found in 3 of 56 stomachs containing food items in 1982 (5.4%); 21 stomachs were empty (Table 16). Spottail shiners were found in 3 of 41 stomachs containing food items in 1983 (7.3%); 13 stomachs were empty (Table 17). The spottail shiners found in walleye stomachs represented 8% of the total volume of food ingested by the 1982 sample and 3% of the food volume eaten by the 1983 sample (Tables 16 and 17). Actual use of spottail shiners and delta smelt may have been higher had the large volume of unknown fish been identifiable (Table 17).

The three walleye containing spottail shiners in 1982 consisted of a 360-mm individual captured in May containing a 151-mm and two

Table 16. Stomach contents of age I and older walleye, Willard Reservoir, 1982 based on percentage volume of food organisms. Percentage frequency of occurrence in parenthesis.

	May	June	July	August	September
Sample size	21	20	20	13	3
Empty (%)	24	25	30	39	0
Fish	99.8 (100)	89.8 (47)	91.7 (93)	98.8 (100)	100.0 (100)
Carp	82.5 (88)	0	8.1 (36)	41.3 (38)	17.1 (33)
Crappie	0	72.0 (38)	3.9 (14)	30.1 (25)	27.3 (67)
Sunfish	0	0	0	5.5 (25)	28.3 (100)
Walleye	0	0.7 (7)	74.7 (21)	0	0
Spottail shiner	10.0 (6)	16.5 (7)	0	7.1 (13)	0
Delta smelt	0	0	0	0	0
Other[a]	7.3 (38)	0.6 (27)	5.0 (43)	14.8 (63)	27.3 (100)
Invertebrates[b]	0	9.8 (73)	8.3 (79)	0.4 (13)	0
Plant matter	0.2 (6)	0.4 (20)	trace (29)	0.8 (13)	

a] Includes mainly unidentified fish, also Gambusia and Utah sucker.

b] Includes Cladocera, Diptera, Ephemeroptera, Anisoptera, Hirudinea, and Lumbricus.

Table 17. Stomach contents of age-I and older walleye, Willard Reservoir, 1983 based on percentage volume of food items. Percentage frequency of occurrence in parenthesis.

	April	June	August
Sample size	20	20	14
Empty (%)	25	35	7
Fish	89.4 (87)	76.4 (31)	98.7 (92)
Carp	16.2 (20)	8.9 (8)	68.5 (62)
Crappie	0	1.1 (8)	2.9 (8)
Green sunfish	8.8 (7)	0	0
Spottail shiner	3.7 (7)	0	4.2 (15)
Delta smelt	0	0	0
Unidentified	48.6 (67)	66.4 (23)	23.1 (62)
Invertebrates[a]	10.4 (27)	8.9 (54)	1.0 (46)
Zooplankton[b]	0.2 (7)	14.7 (46)	0.3 (8)

a] Includes Diptera, Ephemeroptera, Lumbricus, and unidentified insects.

b] Cladocera

unmeasurable spottail shiners, a 400-mm fish captured in June containing a 108-mm shiner, and a 336-mm walleye collected in August which had consumed a 60-mm (yoy) spottail shiner. Hence, walleye in the 336-mm to 400-mm range are capable of consuming all lengths of spottail shiners found in Willard Reservoir.

The three walleye containing spottail shiners in 1983 consisted of a 426-mm fish collected in April containing one spottail shiner approximately 56 mm in length, and two age I+ individuals (221 mm and 229 mm). These age I+ fish were captured in August and each contained one yoy spottail shiner with lengths of about 36 mm and 46 mm, respectively. Hence, yearling walleye in Willard Reservoir were able to utilize yoy spottail shiners at least up to a length of about 46 mm.

To determine if yoy walleye could ingest yoy spottail shiners, body depth of prey fish ingested by the walleye was measured and compared to the measured body depth of spottail shiners collected during the same period of time (Figure 8, Appendix Tables O and P). In most weekly periods, mean body depth of the spottail shiners was larger than the mean body depth of prey fish consumed by the walleye (Figure 8). The largest body depths of ingested prey fish were generally smaller than the measured minimum body depth of spottail shiners at that time (Appendix Tables O and P) suggesting that yoy

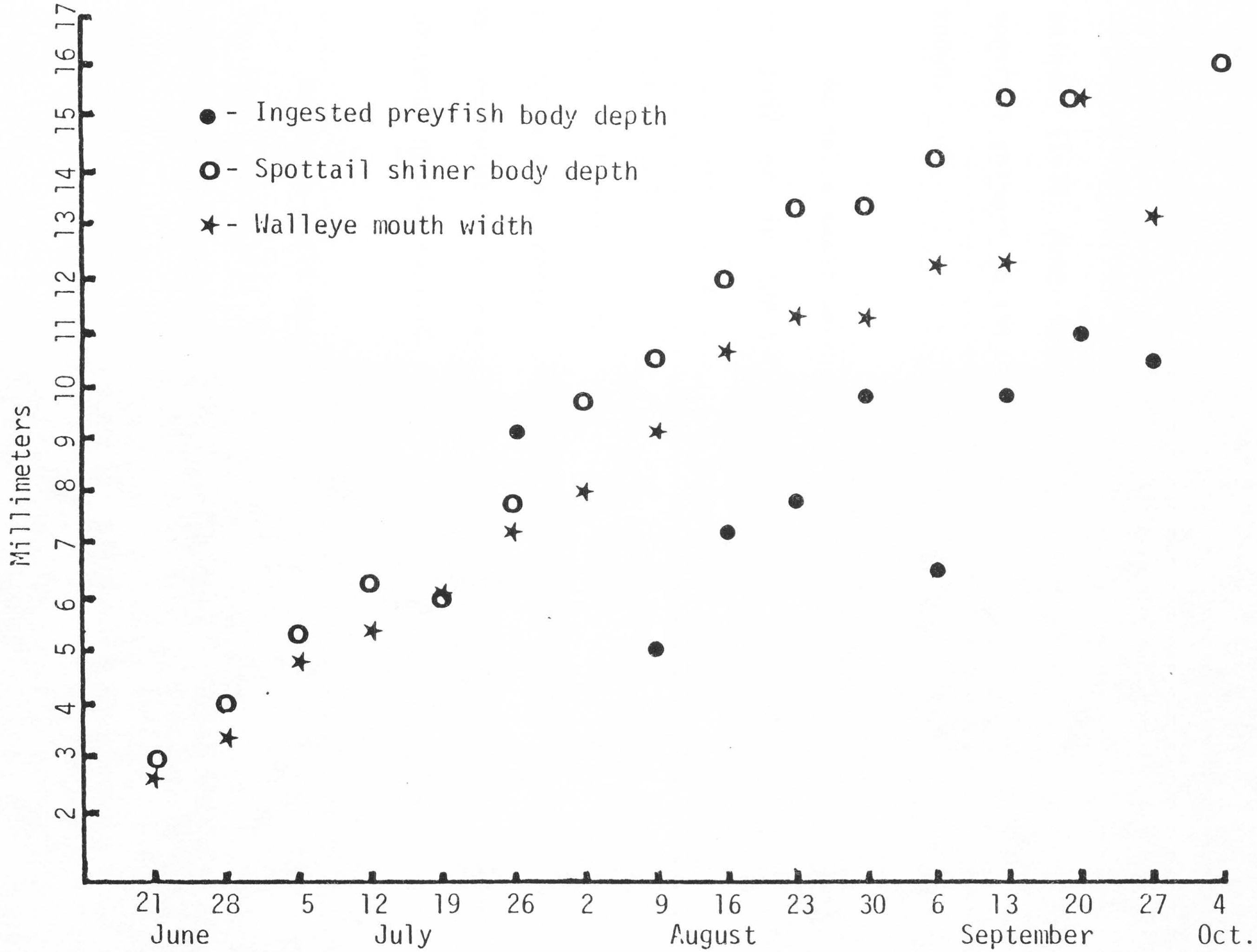

Figure 8. Comparison of yoy walleye mouth width to body depths of yoy spottail shiner and ingested preyfish.

spottail shiners were generally too large for yoy walleye to swallow in 1982. In addition, analysis of the mouth width of the yoy walleye in comparison to the body depth of the spottail shiner at the same time indicated that the walleye were incapable of ingesting yoy spottail shiners on the average (Figure 8). Walleye yoy were consuming larval carp at the probable hatching time of the spottail shiner (1-10 June 1982), and could also have ingested the larval spottail shiners at this time. The reason they did not do so is not known.

No delta smelt were found in stomachs of the 77 walleye examined in 1982 or in the 54 stomachs examined in 1983 (Tables 16 and 17). However, six delta smelt were identified from stomachs of angler-caught walleye in April 1983. The walleye were reportedly males and ranged in length from 356 mm to 406 mm. Estimated length of the delta smelt ranged from 100 mm to 130 mm with a mean length of 116 mm. No relative volumes were available because the entire stomach contents of the individual fish were not examined.

No delta smelt were found in 313 yoy walleye stomachs collected in 1982 (Table 10). Delta smelt yoy collected in June were about the same length as the yoy walleye and were considered too large to be ingested (Appendix Figure A; Tables 8 and 14). One spottail shiner was identified in 1 of the 313 stomachs examined -- a partly-digested individual taken from a 102-mm walleye collected on 9 August 1982.

Crappie

Utilization of spottail shiners and delta smelt by age I and older black crappie was determined by examining 79 crappie stomachs in 1982 and 62 stomachs in 1983. No spottail shiners or delta smelt were found in either year. Crappie stomachs contained very few fish in 1982 or 1983. Centrarchids were found in 2 of 79 (2.5%) and unidentified fish in 1 of 79 (1.3%) black crappie stomachs examined in 1982 (Appendix Table L). Carp were found in 3 of 62 (4.8%) black crappie stomachs examined in 1983 (Appendix Table M). Main food items were cladocerans, dipterans, and corixids. Other food organisms included copepods, amphipods, ephemeropterans, plecopterans, zygopterans, and Hydracarina.

Growth of Walleye in Willard Reservoir

Scales samples were obtained from 81 age I+ and older walleye from Willard Reservoir in 1982. The walleye ranged from age I+ to age IX+. The smallest fish (162 mm TL) was age I+; the largest (677 mm TL) was age IX. Most fish in the sample were age I+ (42%) and ranged in total length from 162 mm to 277 mm (Appendix Table N). Age V and age VI walleye were next in abundance and comprised 15% and 20% of the

1982 catch, respectively.

Mean back-calculated length in millimeters at age I to age IX was 152, 250, 318, 366, 407, 447, 511, 511, and 504, respectively (Table 18). Visual inspection suggested that first- and second-year growth of fish in the 1982 sample had decreased from past years (Figure 9). Growth after age III was comparable or better than found in previous years. The only data that could be compared statistically with present calculated lengths were compiled by Herron (1981) for fish collected in 1979 and 1980. Significant differences ($P \leq 0.05$) in lengths were noted at age I and age II. Another comparison of first- and second-year growth was made by use of just the age II+ fish collected in 1979 by Herron (1981) and the age I+ and age II+ fish from my study. First-year growth of the 1977 year class (237 mm at annulus I) was statistically greater ($P \leq 0.05$) than that of the 1981 year class (147 mm at annulus I). First-year growth of the 1977 year class (237 mm at annulus I) was also statistically greater ($P \leq 0.05$) than that of the 1980 year class (170 mm at annulus I). Second-year growth of 1977 year class (305 mm at annulus II) and 1980 year class (291 mm at annulus II) were not significantly different ($P \geq 0.05$). These modest size differences in first- and second-year growth for 1979 and the 1982 samples, in light of the subjectivity of walleye scale reading, suggests that any difference in growth was biologically insignificant.

Table 18. Mean back-calculated lengths (mm) at annulus formation of age I and older walleye, Willard Reservoir, 1982. Standard deviation of estimates in parenthesis.

Age	No.	Year Class	Body length at annulus- 1	2	3	4	5	6	7	8	9
1	34	1981	147 (17)								
2	5	1980	170 (16)	291 (15)							
3	3	1979	151 (14)	215 (28)	292 (45)						
4	3	1978	134 (12)	201 (25)	285 (67)	322 (80)					
5	12	1977	137 (15)	226 (21)	299 (28)	345 (30)	383 (42)				
6	16	1976	160 (42)	252 (51)	320 (67)	365 (79)	400 (85)	428 (90)			
7	3	1975	189 (37)	313 (86)	389 (92)	434 (105)	490 (112)	522 (121)	544 (122)		
8	3	1974	161 (46)	294 (71)	362 (82)	412 (98)	449 (94)	471 (92)	500 (94)	523 (90)	
9	2	1973	167 (9)	249 (20)	336 (42)	393 (74)	428 (97)	458 (106)	477 (103)	492 (109)	504 (107)
Number			81	47	42	39	36	24	8	5	2
Mean Length			152	250	319	366	407	448	511	511	504
Standard Deviation			(27)	(50)	(61)	(72)	(78)	(94)	(96)	(85)	(107)
Annual Growth Increment			152	98	69	47	41	41	63	0	-7

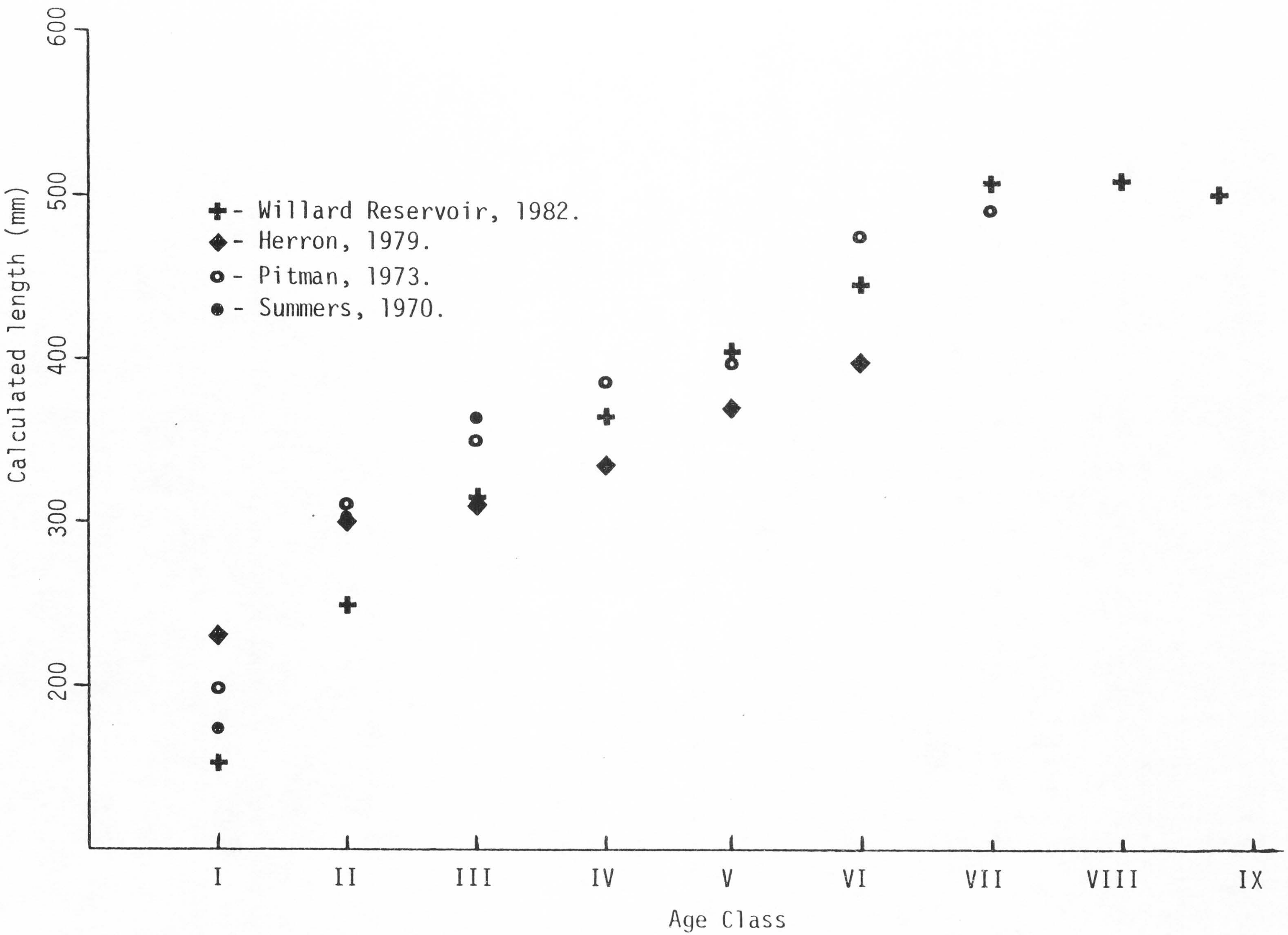

Figure 9. Mean calculated length at each annuli for walleye from Willard Reservoir.

Condition

Mean condition factors (k) were determined for different length groups of walleye collected from Willard Reservoir in 1982 (Table 19). No noticeable change in condition was evident for walleye of the different length groups. Some authors have also found no differences in condition with increasing length while others noticed a slight tendency for the coefficient to increase with increasing length (Colby et al. 1979). The mean k-factor for 74 walleye sampled in 1982 was 0.89 (SD=0.14). The mean k-factor for 40 walleye age II to age IX was 0.95 (SD=0.12). Condition factors for walleye collected at different time periods throughout the year and at different ages may be calculated from the raw data (Appendix Table N).

Table 19. Mean k-factor for walleye of different length groups, Willard Reservoir, 1982.

Length Group	Frequency	Mean Total Length (mm)	Mean Weight (g)	Mean k-factor[a]
160-170	3	164.7	52.3	1.17
170-180	2	173.0	43.0	0.83
180-190	6	184.5	49.2	0.78
190-200	8	192.4	55.0	0.77
200-210	7	205.3	66.4	0.77
210-220	2	215.0	71.0	0.71
220-230	1	227.0	89.0	0.76
240-250	2	243.5	112.5	0.78
260-270	2	264.5	155.0	0.84
270-280	1	277.0	182.0	0.86
310-320	1	319.0	255.0	0.79
320-330	1	326.0	388.0	1.12
330-340	2	336.5	339.5	0.89
340-350	3	345.3	387.0	0.94
350-360	3	358.3	509.3	1.11
360-370	2	365.5	493.5	1.01
370-380	2	377.5	540.0	1.00
380-390	6	384.0	555.2	0.98
390-400	2	398.5	522.5	0.82
400-410	2	406.5	638.5	0.95
410-420	1	415.0	750.0	1.05
420-430	2	430.0	834.0	1.05
430-440	2	434.5	673.0	0.82
440-450	1	448.0	823.0	0.92
460-470	1	470.0	1022.0	0.98
480-490	1	484.0	1092.0	0.96
500-510	2	505.5	1123.5	0.87
570-580	1	572.0	1929.0	1.03
580-590	2	587.0	1660.0	0.82
630-640	1	635.0	1844.0	0.72
650-660	1	657.0	2355.0	0.83
670-680	1	677.0	3200.0	1.03

a] $k = \dfrac{\text{Weight} \times 10^5}{\text{Length}^3}$

DISCUSSION

Evaluation of Stocking Success

The spottail shiner has been an important prey species for piscivorous sportfish throughout its native range (Becker 1983, Parsons 1971, Smith and Kramer 1964), and has been introduced in other western states to improve the forage base. Success of most introductions is poorly documented in terms of population establishment and benefits to sportfish. An example of a probable successful introduction was in Keyhole Reservoir, Wyoming, that was stocked with spottail shiners in 1978 and 1980, gizzard shad (Dorosoma cepedianum) from 1979 to 1983, and yellow perch in 1981. The spottail shiner established a reproducing, expanding population, and condition factors and average size increased dramatically (J. Baughman, Wyoming Game and Fish Department, personal communication). However, no data are available on the extent of utilization of the spottail shiner by the walleye. Spottail shiners were also introduced into Greyrocks Reservoir, Wyoming, in 1982, but fall seining failed to produce yoy spottail shiners (J. Baughman, Wyoming Game and Fish Department, personal communication). Spottail shiners were introduced into Quincy Reservoir, Colorado, and were later found "regularly", but were not considered abundant. The species were not an important food item for most predators, but were found in rainbow trout stomachs (J. Goettl, Colorado Division of Wildlife, personal communication).

The spottail shiner should not be considered successfully established in Willard Reservoir even though evidence of reproduction was found in 1981, 1982, and 1983. Data were insufficient to conclude that the species was maintaining itself by natural reproduction because supplemental stocking in 1982 and 1983 made it difficult to determine the origin of the yoy fish captured. Hence, only when additional stocking is discontinued can it be determined if the fish are naturally sustaining themsleves in the reservoir. Spottail shiners appeared to take at least 5 years to reach stable population levels in Wyoming (J. Baughman, Wyoming Game and Fish Department, personal communication).

California has been the only state reporting the introduction of delta smelt for forage. Wales (1962) originally reported the stocking of pond smelt (*Hypomesus olidus*), but subsequent investigations revealed that the species stocked was actually the delta smelt (*Hypomesus transpacificus nipponensis*) (Wigglesworth 1975; McAllister 1963). Many references to *H. t. nipponensis*, therefore, have been made under the name of pond smelt (*H. olidus*), and care must be taken in using the literature regarding these two species. In addition, the delta smelt is currently listed as *Hypomesus transpacificus* (Robins et al. 1980).

The California Department of Fish and Game introduced the delta smelt (referred to as pond smelt at the time) into six waters in 1959 (Hanson 1972). Subsequently, the species became established in at least three places and reportedly contributed "substantially" to the diets of rainbow trout, brown trout, and largemouth bass in the three reservoirs (Hair and Hanson 1976). For example, in Lake Almanor, California, only two delta smelt were found the year following stocking, however, by April 1974 delta smelt were abundant. By 1975, delta smelt were important in the diet of rainbow and brown trout, silver salmon (Oncorhynchus kisutch), and smallmouth bass (Micropterus dolomieui), and mean weight of smallmouth bass in the creel increased 59% from 1970-73 to 1974-75 (Hair and Hanson 1976). However, reduced growth of kokanee salmon (Oncorhynchus nerka) was evident in the years following the delta smelt introduction.

The present status of the delta smelt in Willard Reservoir is uncertain. Capture of yoy delta smelt in June 1982 suggested that reproduction by the stocked adults had occurred. The finding of six adult smelt in the stomachs of angler-caught walleye in April 1983 indicated over-winter survival of the species. Additionally, these six delta smelt had ripening gonads indicating the potential for spawning that spring. However, no evidence of successful reproduction was found during the 1983 sampling season. The restricted seining areas and the overall large size of the reservoir resulted in a limited sampling effort for the delta smelt. Continued sampling, especially around spawning time in late March and early April, is needed to further investigate survival of delta smelt in Willard Reservoir.

Although neither the spottail shiner nor delta smelt can be considered established in Willard Reservoir, data indicate that the selection of these two species from the many considered, was probably appropriate. Reproduction by both species was found in the form of yoy fish (Tables 4 and 8), and first-year growth compared favorably with growth in native waters (Figures 3 and 4). In addition, yoy spottail shiner and delta smelt utilized the abundant zooplankton and invertebrate food base, with no significant diet overlaps occurring with the yoy walleye or black crappie in 1982 (Figure 5, Table 12).

Diet Similarities Among Species

A concern which often exists with the introduction of exotic forage species into new habitat is the potential competition for available food which results in decreased growth rate of young sportfish (Li et al. 1976; Larkin and Smith 1954). For example, delta smelt in Lake Almanor, California, competed for zooplankton with small trout and coho salmon, kokanee salmon of all sizes, and tui chubs (*Gila bicolor*) (Hair and Hanson 1976). Virtual elimination of the kokanee fishery was attributed to this competition (L. Fisk, California Department of Fish and Game, personal communication). In another example, spottail shiners in Quincy Reservoir, Colorado, were found to feed mainly upon Daphnia sp., and possible competition existed for these cladocerans with rainbow smelt (Osmerus mordax) and yellow perch (J. Goettl, Colorado Division of Wildlife, personal communication).

Food habit analysis of yoy spottail shiners, delta smelt, black crappie, and walleye from Willard Reservoir in 1982 indicated very little diet overlap (Figure 5, Table 12). The low incidence of overlap is attributed to the abundance of preferred food organisms, size differences between the fish species throughout the growing season, and inherent behavioral characteristics causing different resources to be utilized. This same type of food specialization was found for six species of larval fish in Clear Lake, Iowa (Bulkley et al. 1976). Each fish species except shiners seemed to use a different organism or life stage of an organism more than did the other species. In addition, certain early-hatching species shifted their diet as younger larvae of other species began to compete (Bulkley et al. 1976).

At present, food availability is not considered a limiting factor for growth of yoy forage and sport fish in Willard Reservoir. The available food base of zooplankton and invertebrates (mainly Diptera) appears to be under-utilized (Herron 1981). Direct competition for food between young sportfish and forage species would not be expected until the population of forage fish expands.

Utilization of Introduced Forage Species

Walleye were found to utilize both spottail shiner (ages 0+ to II+) and delta smelt during this study. Nevertheless, the two species were not important food items in the diet of walleye probably because of their low relative abundance. Abundant prey species such as carp, green sunfish, bluegill, and crappie (Appendix Tables A-F) evidently buffered much of the predation on spottail shiners and delta smelt. With increased abundance of introduced forage species, utilization should also increase proportionately. Utilization of yoy spottail shiner by yoy walleye was minimal. Only one yoy walleye stomach contained a spottail shiner (Table 10). Spottail shiners generally had greater body depths than the prey fish actually ingested by yoy walleye at corresponding time periods. Analysis of the mouth width of yoy walleye also suggested that they were physically incapable of ingesting most of the yoy spottail shiners (Figure 8).

Carp were a major food item of age I and older walleye in 1982 and 1983 (Tables 16 and 17). This utilization was attributed to greater relative abundance of the species (Appendix Tables A and B). However, the carp is considered unsatisfactory prey because it is too prolific and yoy fish quickly grow out of a suitable size range (Sigler 1958) for most of the walleye. The black crappie was another major food item utilized (Tables 16 and 17). This species was also considered poor forage due its fast growth (Table 15). Holden (1983) found that black crappie also quickly grew out of a suitable forage size for largemouth bass in Mantua Reservoir, Utah.

Predation on yoy walleye by older walleye was evident in Willard Reservoir in 1982 (Table 16). A strong year class of walleye in 1982 (Table 14) and low abundance of other suitable prey items during June and July could have prompted this cannibalism. Increased abundance of forage species during these critical times of the walleyes first year of life should reduce further cannibalism, and thus enhance the population of this important sportfish.

Recommendations

From a research point of view, additional forage introductions should be discontinued and the status of delta smelt and spottail shiners in the reservoir monitored for several years. Successful establishment of both species, utilization by piscivorous fish, and possible increased growth of sportfish that is attributable to the improved forage base could then be determined. If improving the sport fishery at a faster pace is important, then a minimum of 1 year should be allowed to evaluate the introductions while abstaining from further stocking.

A more diverse forage fish community might be a goal for the future management of Willard Reservoir. Species that naturally coexist with the walleye in its native waters would be likely candidates for introduction. These additional species include the emerald shiner, yellow perch, rainbow smelt, fathead minnow, bluntnose minnow, logperch, common shiner, or sand shiner. Criteria for the selection of forage species (Ney 1981, Holden 1983) should again be considered in any additional introductions. A minimum of four successfully established forage species in Willard Reservoir is suggested by the author.

The yellow perch is highly recommended for introduction regardless of the success of other introduced forage species. The species satisfies most of the criteria for a forage fish set forth by

Ney (1981). A close predator-prey relationship between walleye and yellow perch is well documented, with many authors citing the yellow perch as the primary prey for walleye (Colby et al. 1979).

The yellow perch has a reputation of becoming overly abundant particularly in small, infertile lakes, where the population may soon become stunted (Becker 1983). However, large lakes with abundant predator fish and abundant invertebrate forage usually have acceptable perch populations (Becker 1983). Willard Reservoir fits the latter category. Large zooplankton and invertebrate (particularly Diptera) populations would provide a sound forage base for perch. Predator populations of walleye and channel catfish would probably keep perch populations in check.

Possibly more important than its role as forage, the yellow perch could provide an excellent sport fishery. It is a fish that is more easily caught than most other freshwater species and is considered one of the most palatable freshwater fish (Becker 1983). In addition, yellow perch can be caught year-round, with ice fishing often providing a major attraction.

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APPENDICES

Table A. Total number of fish by species captured in shoreline seine hauls, Willard Reservoir, 1982.[a]

Week of-	Temperature (°C)	Walleye yoy	Black crappie yoy	Black crappie older	Spottail shiner yoy	Spottail shiner older	Delta smelt	Bluegill	Green sunfish	*Lepomis* yoy	Channel catfish	Carp	Redside shiner	Black bullhead	*Gambusia*
4/12	7.5			1		17		2	1			1	5		
/19	7.5												11	1	
/26	9.5					1		1	1				1		
5/3	-														
/10	9.0			2				1			1		7	1	
/17	18.0														
/24	16.6										1		1		
/31	18.5	4					1	9					9		
6/7	18.8	24					10					2			
/14	21.4	32		4		1	16	20					1		
/21	26.0	30		2	14	1		3				74	2		
/28	23.9	7		9	12	1	2	9	3		1	17	2		3
7/5	20.9	2	4	1	9	1		6	1		1	24			21
/12	25.0	16	10	1	2			6				2			
/19	27.5	5	33	1		1		2				3	33		1
/26	24.2	2	2		9	1		7		>76		23		25	2
8/2	27.2		17		3			4		>42		>21		128	>56
/9	27.2	3	3		3	4		>25	>53	>50		>22		5	>50
/16	25.3	16	35		2			>100	>100	>50	1	>20		4	>50
/23	27.2	2	145		11	4		>100	>100	>50	2	>8		4	>15
/30	25.6		8	1	8	1		>100	>100	>6	6	3			>100
9/6	25.6	6	22	2	10			>100	>50	>2	3	4			
/13	17.8	12	1		7	1		>1000	>1000		15	1	1		>100
/20	20.5	9	16	5	10	1		>100	>100		8	2	1		>100
/27	12.0	1	6					6	10		10	3			
10/4	11.5	1	2		2			3	20		5	1			
/11	12.0							23	21		16				10

a] Also captured were 2 adult walleye, 1 common shiner, 1 largemouth bass, 13 cottids, and 95 Utah suckers.

Table B. Total number of fish by species captured in shoreline seine hauls, Willard Reservoir, 1983.[a]

Week of-	Temperature (°C)	Walleye yoy	Black crappie yoy	Black crappie older	Spottail shiner yoy	Spottail shiner older	Bluegill	Green sunfish	*Lepomis* yoy	Channel catfish yoy	Carp	Redside shiner	Utah sucker	*Gambusia*
3/21	8.6			36		2	1	3						
/28	8.9			20		2								
4/4	6.1							3						
/11	7.8			2				1				9	2	
/18	10.0			11		1	1	2				5	20	
/25	10.0							1				5	8	
5/2	8.9											8	6	
/9	12.8													
/16	11.1													
/23	18.9			1			1	5				9	16	
/30	24.2						30	3				21	1	
6/6	19.4						13	2			1	4	2	3
/13	20.3						33	5				21		2
/20	20.7		5	7			7	4			10	7		
/27	23.2		79	22	1	1	32	8			16	2	8	1
7/4	23.2	4	>2000	3	8	5	107	15			4		1	19
/11	26.3	12	>1000	1	22	9	>100	4	5		11			23
/18	24.4	4	>600	4	65		31	9	3		16	2		3
/25	24.8		>250	3	24		51	1			28			62
8/1	25.6		>100		1			2			4			
/8	27.9	1	>800		7		2	1	>100	1	>350			33
/15	25.0		>150		17		11	2	>2000	7	54			4
/22	23.5	3	18	1	19		>40	>44	>6000	82	>2000	1	11	
/29	26.4	4	19		9		>250	>100	>2500	307	>2000	2		664
9/5	22.0	1	114		43		>600	>800	>100	597	>1100			93
/12	22.5		467	3	11		1069	659		221	778			86
10/10	17.0		35				127	120			2			4

a] Also captured were 8 age-I or older walleye, 7 sand shiners, 5 brown trout, 1 cutthroat trout, 2 common shiners, 1 hornyhead chub, and 1 black bullhead.

Table C. Total number of fish by species captured by otter trawl, Willard Reservoir, 1982.[a]

Week of-	Number Trawls	Walleye yoy	Black crappie yoy	Black crappie older	Spottail shiner yoy	Bluegill	Green sunfish	Channel catfish	Carp
7/5	4								1
/12	8	12	7	2		1			1
/19	6	14	68	1	1				3
/26	7	9		3	2	30			5
8/2	8	8	26		2	20		2	1
/9	9	8	5		1	48	3	6	4
/16	4	7	135			>100	1		4
/23	0								
/30	6		51			80		1	7
9/6	8	3	35	2		208	7	13	2
/13	5		46			97	2	1	1
/20	7		36	1		189	7		5

a] Also captured were 1 adult spottail shiner and 2 adult walleye.

Table D. Total number of fish by species captured by otter trawl, Willard Reservoir, 1983.[a]

Week of-	Number Trawls	Black crappie yoy	Black crappie older	Spottail shiner yoy	Bluegill	Channel catfish	Carp
6/27	14	30	8			1	6
7/11	5	9	2				14
/18	7	36	3		1		
/25	6	315	1	1	16		2
8/7	7	36	4	1	8	5	69

a] Also captured were 2 age I and older walleye, 1 adult spottail shiner, 1 black bullhead, and 1 Utah sucker.

Table E. Total number of yoy fish by species captured in larval fish tows, Willard Reservoir, 1982.

Week of-	Number Tows	Walleye	Bluegill	Green sunfish	*Lepomis* sp.	Carp
4/19	9					
/26	7	12				
5/3	10	16				
/10	12	5				
/17	17	4				
/24	5	1				
/31	10	1				3
6/7	12					13
/14	6					37
/21	12	1				161
/28	12					147
7/5	6					32
/12	6					14
/19	6					42
/26	6				1	21
8/2	6				12	16
/9	6			3	27	33
/16	5			4	10	6
/23	6				4	1
/30	6		1		6	
9/6	6				2	
/13	6		1			
/20	6					

a] Also captured were 4 channel catfish, 1 black crappie, and 3 unidentified larval fish.

Table F. Total number of yoy fish by species captured in larval fish tows, Willard Reservoir, 1983.

Week of-	Number Tows	Black crappie	*Lepomis* sp.	Channel catfish	Carp	Unident.
4/25	6					
5/2	12					
/9	12					
/16	12					
/23	24					1
/30	24				576	
6/6	18	2			1939	
/13	12	23			806	3
/20	8	3			140	
/27	3	1			39	
7/4	5	3			12	
/11	8		5		68	
/18	12	2	1		102	
/25	12				95	
8/1	6			10	59	1
/8	6			3	7	2
/15	6		4	1	15	
/22	6		10	10	2	1

Table G. Mean total length (mm) of yoy channel catfish collected by various gear from Willard Reservoir, 1982 and 1983 (N=sample size).

1982

Week of-	N	Mean	Range	Std. Dev.
8/2	2	18.3	18-19	0.35
/9	5	19.1	17-28	4.71
/16	1	32.5	32.5	0.0
/23	4	25.4	17-39	9.90
/30	6	43.1	33-50	5.98
9/6	14	52.0	42-60	5.60
/13	16	52.4	39-64	6.15
/20	7	56.3	50-66	6.21
/27	10	55.5	47-63	5.15
10/4	5	57.8	46-66	7.79
/11	16	61.1	51-74	5.93

1983

Week of-	N	Mean	Range	Std. Dev.
8/1	10	18.5	18-20	0.58
/8	7	20.0	17-24	2.81
/15	8	30.8	22-34	4.03
/22	41	32.5	16-50	8.71
/29	32	36.5	31-44	3.63
9/5	30	41.0	31-64	6.27
/12	30	44.3	36-54	5.24

Table H. Mean total length (mm) of yoy green sunfish collected by various gear from Willard Reservoir, 1982 and 1983 (N=sample size).

1982

Week of-	N	Mean	Range	Std. Dev.
7/26	4	23.5	21-25	1.68
8/2	15	25.0	17-25	4.60
/9	56	26.0	14-45	7.99
/16	35	25.9	19-37	3.29
/23	40	30.0	19-38	4.55
/30	28	31.5	17-44	7.82
9/6	12	34.4	29-41	8.03
/13	31	35.6	24-52	6.96
/20	38	35.1	24-51	8.26
/27	10	29.6	17-56	12.00
10/4	20	33.9	26-50	6.59
/11	21	38.3	20-59	11.22

1983

Week of	N	Mean	Range	Std. Dev.
8/22	44	21.5	16-29	3.52
/29	30	26.7	16-33	3.83
9/5	30	28.2	16-37	5.87
/12	30	33.4	25-40	3.82
/19				
/26				
10/3				
/10	14	29.2	25-34	3.19

Table I. Mean total length (mm) of yoy bluegill collected by various gear from Willard Reservoir, 1982 and 1983 (N=sample size).

1982

Week of-	N	Mean	Range	Std. Dev.
7/26	10	21.5	19-24	1.55
8/2	16	23.1	20-28	2.48
/9	65	25.2	15-39	5.18
/16	60	25.5	18-41	5.48
/23	30	27.7	19-38	5.87
/30	106	29.2	13-49	8.35
9/6	40	30.3	20-44	6.60
/13	38	35.5	23-49	5.00
/20	103	33.6	16-55	7.35
/27	6	34.3	26-48	8.55
10/4	3	38.0	26-54	14.40
/11	23	28.5	22-34	2.39

1983

Week of-	N	Mean	Range	Std. Dev.
8/8	2	24.5	23-26	2.12
/15	11	21.7	20-33	3.87
/22	40	22.6	18-30	2.55
/29	30	27.3	17-42	6.23
9/5	30	31.1	25-37	2.13
/12	30	34.2	22-45	5.08
/19				
/26				
10/3				
/10	20	33.2	21-41	7.19

Table J. Mean total length (mm) of yoy *Lepomis* sp. collected by various gear from Willard Reservoir, 1982 and 1983 (N=sample size).

1982

Week of-	N	Mean	Range	Std. Dev.
7/19	33	14.3	12-17	1.17
/26	38	16.7	12-22	2.92
8/2	42	15.5	11-21	2.20
/9	32	13.1	5-19	4.50
/16	19	12.6	7-16	2.15
/23	4	14.8	12-17	2.36
/30	6	15.8	14-19	3.00
9/6	2	15.0	13-18	4.24

1983

Week of-	N	Mean	Range	Std. Dev.
7/11	5	8.5	8-12	1.70
/18	3	13.0	13-14	0.50
/25				
8/1				
/8	43	14.7	7-18	2.49
/15	34	14.5	8-20	2.89
/22	28	14.3	8-19	2.68

Table K. Mean total length (mm) of yoy carp collected by various gear from Willard Reservoir, 1982 and 1983[a] (N=sample size).

1982

Week of-	N	Mean	Range
5/31	3	7.0	7-8
6/7	13	6.9	7-8
/14	36	7.5	6-9
/21	70	10.3	8-16
/28	47	11.4	6-22
7/5	46	13.9	7-49
/12	17	11.6	7-23
/19	23	9.8	7-18
/26	48	35.3	6-75
8/2	37	28.9	7-81
/9	53	28.7	6-83
/16	12	29.7	9-86
/23	10	51.1	12-73
/30	10	48.5	27-82
9/6	4	79.5	46-123
/13	2	71.5	71-72
/20	1	53.0	53
/27	3	81.7	51-106
10/4	1	119.0	119

1983

Week of-	N	Mean	Range
5/30	60	6.3	6-7
6/6	60	7.8	6-9
/13	60	9.4	8-12
/20	43	10.0	8-17
/27	44	13.0	9-37
7/4	12	7.9	7-11
/11	62	13.3	8-30
/18	69	12.5	7-28
/25	78	12.6	6-37
8/1	34	13.8	8-46
/8	97	35.0	9-71
/15	45	33.5	8-70
/22	32	54.3	9-90
/29	30	55.0	39-79
9/5	30	50.7	33-76
/12	30	59.1	43-81
10/10	2	64.0	54-74

a] Standard deviations were not included due to the inconsistency of capture of different size groups.

Table L. Seasonal percentage frequency of occurrence (estimated percentage volume in parenthesis) of food items in age I and older black crappie stomachs, Willard Reservoir.

Item	May 1982 (n=20)	June 1982 (n=20)	July 1982 (n=20)	August 1982 (n=17)	September 1982 (n=2)
Zooplankton	100 (74)	50 (7)	85 (17)	82 (50)	100 (67)
Cladocera	100 (74)			82 (50)	100 (67)
Copepoda	10 (<1)				
Invertebrates	100 (26)	100 (93)	100 (81)	100 (43)	100 (33)
Diptera	100 (5)	100 (74)	90 (13)	76 (31)	100 (23)
Corixidae	100 (3)	35 (2)	80 (48)	47 (3)	50 (5)
Amphipoda	10 (<1)		25 (1)	24 (3)	
Other[a]	100 (18)	95 (17)	95 (19)	88 (6)	100 (5)
Fish			5 (2)	12 (7)	
Centrarchidae				12 (7)	
Unidentified			5 (2)		

a] Includes Ephemeroptera, Plecoptera, Zygoptera, Hydracarina, and Notonectidae.

Table M. Seasonal percentage frequency of occurrence (estimated percentage volume in parenthesis) of food items in age I and older black crappie, Willard Reservoir.

Item	March 1983 (n=24)	July 1983 (n=20)	August 1983 (n=18)
Zooplankton	100 (85)	40 (10)	78 (24)
Cladocera	100 (85)	40 (10)	78 (24)
Copepoda	0	0	0
Invertebrates	100 (15)	100 (90)	100 (69)
Diptera	54 (2)	95 (50)	89 (33)
Corixidae	100 (9)	95 (21)	83 (30)
Amphipoda	63 (2)	0	28 (3)
Other[a]	46 (2)	45 (19)	11 (3)
Fish	0	0	17 (7)
Carp	0	0	17 (7)
Other[b]	0	10 (<1)	0

a] Includes Notonectidae, Ephemeroptera, Anisoptera, and unidentified insects.

b] Includes fish eggs and plant matter.

Table N. Length, weight, k-factor, and age of walleye, Willard Reservoir, 1982.

Dates Collected	Length (mm)	Weight (g)	k-factor	Age
5/5	504	1055	0.82	VI+
"	430	823	1.04	VI
"	430	845	1.06	VI+
"	436	-	-	VII+
"	355	405	0.91	VI
"	415	750	1.05	VI
"	326	388	1.12	V
"	342	391	0.98	V
"	381	550	0.99	V+
"	360	540	1.16	V
"	366	570	1.16	VI
"	375	515	0.98	VI
"	381	655	1.18	V
"	384	558	0.99	V
"	388	532	0.91	V
"	386	596	1.04	VI
"	677	3200	1.03	IX
"	360	533	1.14	VI
"	337	346	0.90	VI
"	347	413	0.99	III+
"	380	565	1.03	IV+
6/18-29	162	57	1.34	I+
"	169	57	1.18	I+
"	384	440	0.78	VI+
"	507	1192	0.91	VIII+
"	590	1760	0.86	VII+
"	163	43	0.99	I+
"	319	255	0.79	II+
"	470	1022	0.98	VI+
"	572	1929	1.03	VI+
"	642	-	-	IX+
"	407	539	0.80	V+
"	400	596	0.93	V+
"	406	738	1.10	V+
"	191	48	0.69	I+
"	173	40	0.77	I+
"	185	45	0.71	I+
"	208	67	0.74	I+
"	214	67	0.68	I+
"	181	44	0.74	I+
"	180	44	0.75	I+

Table N. (continued)

Dates Collected	Length (mm)	Weight (g)	k-factor	Age
7/15-20	207	65	0.73	I+
"	185	47	0.74	I+
"	173	46	0.89	I+
"	191	55	0.79	I+
"	187	57	0.87	I+
"	192	57	0.81	I+
"	193	59	0.82	I+
"	191	54	0.77	I+
"	245	111	0.75	I+
"	197	61	0.80	I+
"	206	69	0.79	I+
"	200	60	0.75	I+
"	208	69	0.77	I+
"	189	58	0.86	I+
"	208	73	0.81	I+
"	216	75	0.74	I+
"	200	67	0.78	I+
"	191	53	0.76	I+
"	193	53	0.74	I+
"	437	651	0.78	V+
8/24-31	267	153	0.80	I+
"	336	333	0.88	II+
"	397	449	0.72	III+
"	432	695	0.86	V+
"	448	823	0.92	VI+
"	635	1844	0.72	VIII+
"	365	417	0.86	II+
"	347	357	0.85	III+
"	227	89	0.76	I+
"	242	114	0.80	I+
"	262	157	0.87	I+
"	277	182	0.86	I+
9/29-11/26	584	1560	0.78	VI+
"	484	1092	0.96	VI+
"	651	2355	0.85	VIII+
"	317	-	-	IV+
"	336	-	-	II+
"	334	-	-	II+
"	356	-	-	IV+
"	658	-	-	VII+

Table 0. Relation of yoy walleye mouth width to body depth of ingested preyfish, Willard Reservoir, 1982. Measurements in millimeters, standard deviation in parenthesis.

Week of-	Walleye Mouth Width			Preyfish Body Depth		
	No.	Mean	Range	No.	Mean	Range
7/26	11	7.2 (1.41)	4.6-10.1	1	9.1	9.5
8/2	8	7.9 (0.79)	7.1-9.1			
/9	9	9.1 (0.73)	7.3-9.7	1	5.0	5.0
/16	22	10.7 (1.42)	8.4-14.2	5	7.1 (0.74)	6.0-8.0
/23	25	11.3 (1.38)	9.4-14.3	24	7.8 (1.35)	5.5-11.0
/30	23	11.2 (1.27)	8.8-15.1	8	9.7 (1.49)	7.0-12.0
9/6	9	12.3 (1.62)	10.2-15.0	2	6.5 (2.12)	5.0-8.0
/13	4	12.4 (2.59)	9.0-15.3	6	9.8 (2.16)	7.0-13.0
/20	9	15.2 (1.68)	12.6-17.2	5	11.0 (1.46)	10.0-13.5
/27	21	13.1 (1.80)	10.0-16.4	21	10.5 (2.00)	7.0-14.0

Table P. Relation of yoy walleye mouth width to body depth of yoy spottail shiner, Willard Reservoir, 1982. Measurements in millimeters, standard deviation in parenthesis.

Week of-	Walleye Mouth Width			Spottail shiner Body Depth		
	No.	Mean	Range	No.	Mean	Range
6/21	20	2.7 (0.34)	2.0-3.6	14	3.0 (0.56)	2.0-4.0
/28	7	3.3 (0.68)	2.2-4.3	12	4.0 (0.38)	3.5-4.5
7/5	2	4.8 (0.07)	4.7-4.8	9	5.2 (0.57)	4.5-6.5
/12	29	5.3 (0.65)	4.4-6.8	2	6.3 (0.35)	6.0-6.5
/19	20	6.1 (0.60)	4.9-7.1	1	6.0	6.0
/26	11	7.2 (1.41)	4.6-10.1	11	7.7 (1.15)	6.5-9.0
8/2	8	7.9 (0.79)	7.1-9.1	5	9.7 (0.76)	9.0-11.0
/9	9	9.1 (0.73)	7.3-9.7	4	10.5 (0.71)	10.0-11.5
/16	22	10.7 (1.42)	8.4-14.2	2	12.0 (0.71)	11.5-12.5
/23	25	11.3 (1.38)	9.4-14.3	13	13.3 (1.03)	11.5-15.0
/30	23	11.2 (1.27)	8.8-15.1	8	13.3 (1.07)	12.0-15.0
9/6	9	12.3 (1.62)	10.2-15.0	10	14.2 (1.53)	12.0-17.0
/13	4	12.4 (2.59)	9.0-15.3	7	15.3 (1.25)	14.0-17.5
/20	9	15.2 (1.68)	12.6-17.2	10	15.2 (1.01)	13.5-16.5
/27	21	13.1 (1.80)	10.0-16.4	0	0	
10/4	0	0		2	16.0 (1.41)	16.0-17.0

Table Q. Mean lengths (mm) of selected invertebrates eaten by yoy spottail shiner (SS), walleye (W), and black crappie (BC), Willard Reservoir, 1982 (n=number of fish containing that food item).

Week of-	6/21			6/28			7/5			7/12		
	SS	W	BC	SS	W	BC	SS	W	BC	SS	W	BC
Mean TL (mm)	14	40		21	49		29	63	15	35	65	22
Cladocerans												
Daphnia		1.3 (n=2)		1.6 (n=2)				1.4 (n=2)			1.9 (n=15)	
Other[a]	0.3 (n=2)	1.1 (n=2)		0.6 (n=1)	1.1 (n=1)				0.6 (n=5)	0.5 (n=1)	1.5 (n=2)	0.6 (n=6)
Copepods												
Diaptomus		1.2 (n=4)			1.3 (n=1)			1.2 (n=1)	0.9 (n=5)		1.2 (n=4)	0.9 (n=7)
Cyclops		1.1 (n=10)			1.1 (n=2)				0.7 (n=4)			0.7 (n=6)
Dipterans												
Chironomid larvae	1.9 (n=8)	4.3 (n=8)		2.6 (n=5)	4.0 (n=1)		2.4 (n=9)			2.5 (n=1)	4.7 (n=3)	
Chaoborid larvae		7.0 (n=3)						8.0 (n=1)			7.4 (n=5)	4.9 (n=2)
Dipteran pupae		4.5 (n=5)		4.3 (n=1)	5.8 (n=4)			10.0 (n=1)		4.5 (n=1)	4.9 (n=9)	

[a]Includes *Bosmina* and unidentified cladocerans.

Table Q. (continued)

Week of-	7/19			7/26			8/2			8/9		
	SS	W	BC	SS	W	BC	SS	W	BC	SS	W	BC
Mean TL (mm)	34	83	35	43	92	43	55	100	52	57	107	58
Cladocerans												
<u>Daphnia</u>		1.9 (n=16)	1.1 (n=7)		1.8 (n=7)	1.1 (n=2)	1.9 (n=1)	1.9 (n=6)	1.3 (n=10)	1.4 (n=1)	2.1 (n=7)	1.4 (n=7)
Other[a]			0.6 (n=10)	0.9 (n=1)		0.5 (n=2)	0.6 (n=1)		0.6 (n=10)	1.2 (n=1)		0.5 (n=6)
Copepods												
<u>Diaptomus</u>		1.1 (n=1)	0.9 (n=7)			0.9 (n=2)		1.9 (n=1)	1.1 (n=9)			0.9 (n=5)
<u>Cyclops</u>		1.3 (n=1)	0.9 (n=8)			0.9 (n=2)			1.1 (n=10)			1.0 (n=5)
Dipterans												
Chironomid larvae	3.4 (n=1)	5.8 (n=7)	2.8 (n=2)	3.6 (n=10)	5.8 (n=3)		4.3 (n=3)	8.8 (n=6)		3.0 (n=1)	7.0 (n=2)	3.7 (n=2)
Chaoborid larvae		7.1 (n=4)	5.0 (n=6)		7.1 (n=3)	3.0 (n=1)		7.0 (n=6)	4.5 (n=9)	6.0 (n=1)	7.2 (n=5)	5.3 (n=7)
Dipteran pupae		6.1 (n=7)	5.0 (n=1)	3.2 (n=3)	6.3 (n=5)			9.8 (n=4)			7.0 (n=7)	4.8 (n=2)

Table Q. (continued)

Week of-	8/16			8/23			8/30			9/6		
	SS	W	BC	SS	W	BC	SS	W	BC	SS	W	BC
Mean TL (mm)	66	118	57	72	135	61	73	139	68	78	157	70
Cladocerans												
Daphnia		2.3 (n=15)	2.0 (n=10)		2.5 (n=3)	2.0 (n=10)		2.5 (n=15)	1.6 (n=10)		2.0 (n=2)	1.5 (n=10)
Other[a]			0.6 (n=10)			0.7 (n=10)	1.1 (n=1)		0.7 (n=10)			0.6 (n=10)
Copepods												
Diaptomus			0.9 (n=10)			1.0 (n=10)			0.9 (n=9)			1.0 (n=10)
Cyclops			1.2 (n=5)			1.0 (n=6)			1.1 (n=7)			1.1 (n=10)
Dipterans												
Chironomid larvae	6.5 (n=2)	5.3 (n=3)	3.6 (n=2)	3.3 (n=7)	6.1 (n=3)	2.9 (n=3)		5.5 (n=1)	3.3 (n=6)	3.8 (n=2)	7.0 (n=1)	2.5 (n=2)
Chaoborid larvae		7.1 (n=5)	2.9 (n=2)	6.0 (n=1)			3.0 (n=1)		3.4 (n=2)			3.6 (n=7)
Dipteran pupae	3.5 (n=1)	5.3 (n=3)	3.5 (n=2)	4.0 (n=3)	6.8 (n=6)			7.3 (n=4)	4.1 (n=4)		12.0 (n=1)	

Table Q. (continued)

Week of-	9/13			9/20			9/27			10/4		
	SS	W	BC	SS	W	BC	SS	W	BC	SS	W	BC
Mean TL (mm)	83	150	74	84	160	82		162	79	86	137	92
Cladocerans												
<u>Daphnia</u>		1.5 (n=2)	1.4 (n=5)			1.3 (n=8)		1.8 (n=4)				1.6 (n=2)
Other[a]		1.1 (n=2)	0.7 (n=10)			0.8 (n=12)			0.5 (n=1)	1.3 (n=1)		
Copepods												
<u>Diaptomus</u>			1.0 (n=5)			0.8 (n=20)			0.9 (n=3)			1.1 (n=2)
<u>Cyclops</u>			1.3 (n=5)									
Dipterans												
Chironomid larvae			4.3 (n=3)	4.3 (n=3)		4.6 (n=7)				4.0 (n=1)		
Chaoborid larvae			6.3 (n=3)			7.0 (n=1)						
Dipteran pupae	7.3 (n=1)	6.5 (n=2)	6.7 (n=5)		8.8 (n=3)	7.0 (n=10)						9.0 (n=1)

Appendix B

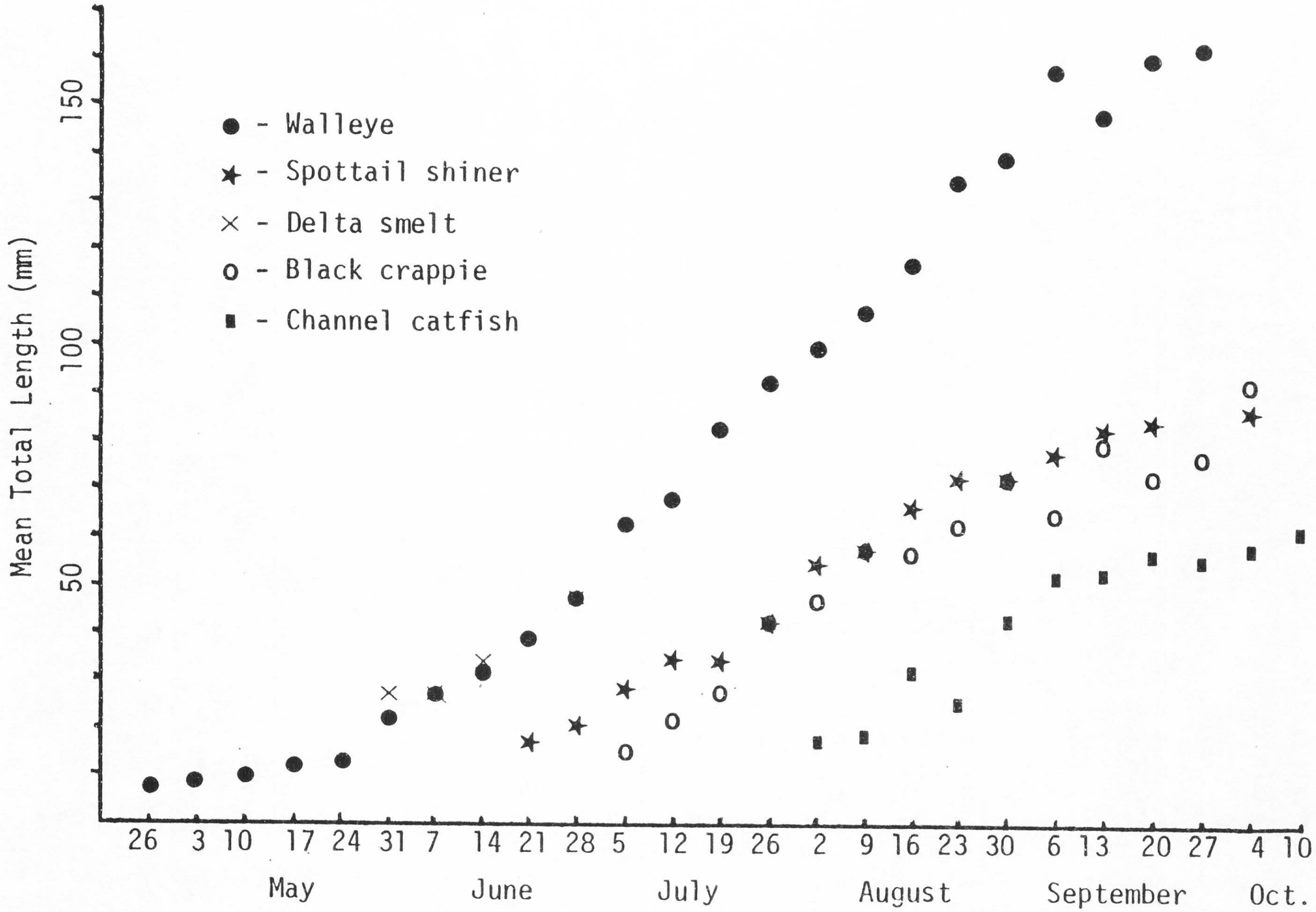

Figure A. Mean total lengths of selected yoy fish collected weekly from Willard Reservoir, 1982.

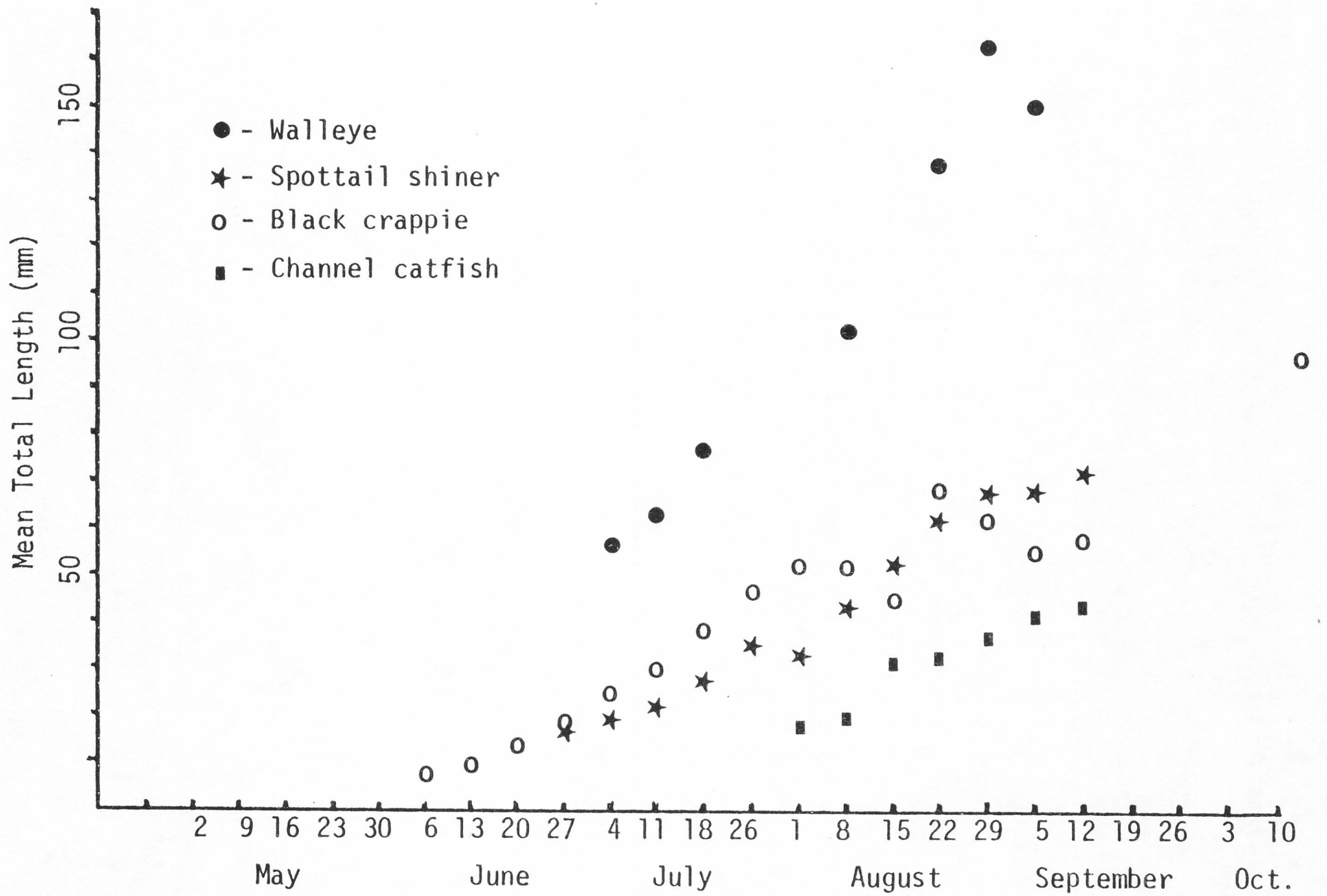

Figure B. Mean total lengths of selected yoy fish collected weekly from Willard Reservoir, 1983.